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PHYTOPATHOLOGY

VOLUME VI NUMBER 3

JUNE, 1916

PERIDERMIUM HARKNESSII AND CRONARTIUM QUERCUUM[1]

E. P. MEINECKE

WITH TWO FIGURES IN THE TEXT

INTRODUCTION

Peridermium harknessii was first reported on the Pacific Coast on *Pinus radiata* by Moore; Farlow and Seymour's[2] Host Index adds *P. contorta*, *P. ponderosa* and *P. sabiniana* to the list. Hedgcock[3] further reports it on *P. jeffreyi*. The writer has found it very common on *Pinus attenuata*, and occasionally also on *P. coulteri*. Of all these hosts *P. radiata*, *sabiniana*, *attenuata* and *contorta* are undoubtedly most subject to attacks from the fungus. Numerous galls appear on the same tree. The writer has counted thirty-seven galls on a sapling of *Pinus radiata*, three feet high, selected at random from a group of similarly affected trees. Another specimen contained thirty-four galls on a witches'-broom fourteen inches high which had developed from a large old gall on the main stem. Another tree (diameter at base three inches, height eight feet) had 173 galls. A fourth tree (diameter at base six inches, height twelve feet) carried not less than 529 galls.

There can be little doubt but that each gall is the result of an individual infection. The tissues, even between neighboring galls, are perfectly normal, and rather commonly a tree develops only one gall, which may grow to large size. Unless the mycelium kills its substratum, as is often the case, it may grow and cause the gall to enlarge for many years, but it is always strictly confined to the gall itself and its immediate surroundings.

[1] A preliminary note appeared in Science, n.s. **43**: 73. 1916.

[2] Farlow, W. G. and Seymour, A. B. A provisional host index of the fungi of the United States, Part III, pp. 160–162.

[3] Hedgcock, G. G. Notes on some western Uredinae which attack forest trees. Mycologia **4**: 143. 1912.

The mycelium is unable to spread from the initial point of infection and thus produce a gall at some distant point.

The typical *Peridermium harknessii* very much resembles *Peridermium cerebrum* Peck. Since Shear[4] has proved that *Peridermium cerebrum* has as its alternate stage *Cronartium Quercuum* (Berk.), the occurrence of a Cronartium on *Quercus agrifolia* in California[5] made it appear possible that the two Peridermia were identical. Hedgcock and Long[6] call the eastern form on oak *Cronartium cerebrum*. The identity of the Californian Cronartium on oak with the eastern form not being definitely proved by inoculation, the old name *Cronartium Quercuum* in Shear's sense is, for convenience's sake, used in this paper.

The writer has found *Cronartium Quercuum* in its telial form in the immediate vicinity of *Pinus radiata* only on *Quercus agrifolia* near Monterey, Palo Alto and Menlo Park, California. Near the latter two places collections were also made by Mr. J. T. McMurphy. *Pinus radiata* in its natural range occurs only in an extremely limited area on the coast, but is planted extensively. *Quercus agrifolia* is common along the coast from Mendocino south, but does not even penetrate into the great valleys of the Sacramento and San Joaquin Rivers, much less into the Sierra Nevada, where *Peridermium harknessii*, so-called, is very common on *Pinus sabiniana*, *P. ponderosa* and *P. jeffreyi*, and above all, on *P. contorta*. In the regions inhabited by these pines other oaks, particularly *Quercus californica* and *Castanopsis chrysophylla* are common, both of which Hedgcock has successfully inoculated with aeciospores of *Peridermium cerebrum*. It is, therefore, still possible, that *Quercus californica* and *Castanopsis chrysophylla* or perhaps some of the other associated oaks, may be the alternate hosts of the so-called *Peridermium harknessii* on some of the Sierra Nevada pines. Farlow and Seymour (p. 161) name *Pinus ponderosa* as a host for *Peridermium cerebrum* Pk. However, no Cronartium has been found, to the writer's knowledge, on *Quercus californica* or *Castanopsis chrysophylla* in California.

Cronartium Quercuum is by no means common on *Quercus agrifolia* in the vicinity of *Pinus radiata*. In fact, one may say without exaggeration, that there seems to be no direct relation between the distance of oak from infected pines and the frequency of the Cronartium, even where the oak is standing close to heavily infected pines. Never very abundant, it is found as common on oaks standing isolated or one hundred to two

[4] Shear, C. L. Peridermium cerebrum Peck and Cronartium Quercuum (Berk.) Journ. Myc. **12**: 89. 1906.

[5] Arthur, J. C. North American Flora, **7**[2]: 122.

[6] Hedgcock, G. G. and Long, W. H. Identity of Peridermium fusiforme with Peridermium cerebrum. Journ. Agr. Res. **2**: 247. 1914.

FIG. 1. Gall of Peridermium harknessii on Pinus radiata with aecium. Result of direct aecial infection. Note the sharp line of demarcation at the basal end and the incipient witches'-broom formation in connection with the gall.

hundred yards and more from the nearest pines as on those in closest proximity to Peridermium galls. In the midst of an unusually heavy infection of Peridermium it is not uncommon to find the oaks immediately

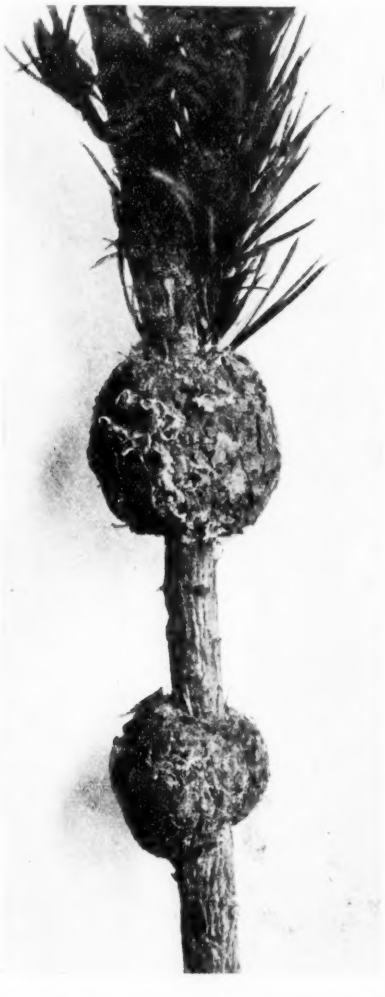

FIG. 2. Typical older gall of Peridermium harknessii on Pinus radiata from type locality. The aecia are confluent but not typically cerebroid.

adjoining infected pines quite free from Cronartium. In many cases where old, richly sporulating galls stand within a foot of the nearest oak branches, so close that in a heavy wind they must necessarily touch each other, the oak leaves were found to be without a sign of Cronartium.

The infection of the oak leaves is not heavier in the lee of pines with richly sporulating galls than in other sites, although here, close to the ocean, the prevailing winds are very constant. The very uneven distribution of the fungus on *Quercus agrifolia* may find its explanation in racial characteristics and susceptibilities of the oak. The telial form on *Quercus agrifolia* is even less frequent than the uredenial form. The writer has found the latter locally plentiful on *Quercus densiflora* and *Quercus chrysolepis* along the Coast to the Oregon line, always without the telial form. On the Klamath River in the northwestern part of California near the coast the writer collected a uredenial form on *Quercus chrysolepis*, which caused a distinct witches'-broom. Possibly this is a new form; the formation of witches'-brooms, it seems, has never been observed in other uredinial infections on oak. Another Cronartium received through the courtesy of Messrs. J. T. McMurphy and J. W. Sheldon was collected in the middle of May in the Coast Range near Palo Alto, California on *Quercus durata*. *Quercus durata* is an evergreen shrub. The collection comes from a region where *Peridermium harknessii* is common on *Pinus attenuata* and *P. radiata*. Whether any of these pines occurred in the immediate vicinity of the infected oaks is not known.

Hedgcock[7] was successful in infecting several California oaks (*Quercus lobata*, *Q. densiflora*, *Q. californica*) and also *Castanopsis chrysophylla* with aeciospores from *Peridermium cerebrum*. His inoculations of two pines, *Pinus ponderosa* and *P. murrayana* (*contorta*), which are common bearers of the so-called *Peridermium harknessii* in California, with teliospores, supposedly from *Quercus rubra*, produced typical galls of *Peridermium cerebrum*. On the other hand, his inoculations of oaks with material of *Peridermium harknessii* on *Pinus radiata* from California, failed.

In 1912 Hedgcock[8] again reports that "repeated and careful inoculation with aeciospores of this Peridermium (*P. harknessii*) on the leaves of young oaks of a number of species failed to infect them, while at the same time, inoculation with *Peridermium cerebrum* Peck on the same species of oak trees brought about an infection, resulting in the uredinia and telia of *Cronartium Quercuum* (Brond.) Arth."

The possibility that these failures were due to loss of viability of the spores in transit prompted the writer repeatedly to try inoculations with fresh material on *Quercus agrifolia* and *Q. californica*. All these attempts were without success.

[7] Notes on Peridermium cerebrum Peck and Peridermium harknessii Moore. Phytopath. **1**:131. 1911.

[8] Mycologia **4**: 143.

Strong as are the reasons for assuming that *Peridermium harknessii* is identical with *Peridermium cerebrum*, there are well-founded considerations which make it imperative that the connection should actually be proved by inoculation. One of these is the apparent independence of *Cronartium Quercuum* and *Peridermium harknessii*. Another is the difference in appearance. The aecia of *Peridermium harknessii*, at least on *Pinus radiata*, are not typically cerebroid (fig. 2); they usually appear as separate sori and the rather delicate peridium breaks open very soon after coming up through the bark. A comparison of figure 2 and Hedgcock and Long's photographs (their plate XI) show the difference very plainly. More important is the apparent rarity in our Peridermium of pycnia exuding "abundantly a yellowish, sweet fluid" as on *Peridermium cerebrum*,[9] which are also mentioned by Shear.[10] In spite of diligent search the writer has only once succeeded in finding pycnia of *Peridermium harknessii* on a young gall on *Pinus jeffreyi* in early spring (April). The pycnia contained very small pycnospores and did not break through the bark. In the literature the writer does not find any other reference to pycnia on *Peridermium harknessii*. To these distinctions may be added the fact that in infections with *Peridermium harknessii*, particularly on *Pinus radiata*, *P. contorta* and *P. attenuata*, witches'-brooms are extremely common and that the galls very often continue to fruit for many years, both of which phenomena are rare in *Peridermium cerebrum* according to Hedgcock.[11] It is well to remember also, that all the numerous and careful attempts at infection of *Quercus agrifolia* with aeciospores of *Peridermium harknessii* have failed.

The typically spindle-shaped form (*Peridermium fusiforme*) which has recently been proved by Arthur and Kern[12] and by Hedgcock and Long (l.c.) to be identical with *Peridermium cerebrum*, apparently does not exist on the Pacific Coast or at least is very rare. The typical gall of *Peridermium harknessii* is always very well defined; the transition from stem to gall is never gradual, but always very abrupt. When the infection takes place in 1- and 2-years-old twigs, the swelling generally embraces the whole stem; in the next year these galls often take the shape of a pear, with the thick part downwards, and later become spherical. On a little older stems the swelling may be one-sided and later develop into a hemisphere. But whatever form the gall takes, it is always very clearly set off against the unthickened stem; this is particularly noticeable

[9] Mycologia **4**: 132.

[10] Jour. Myc. **12**: 91.

[11] Mycologia **4**: 143.

[12] Arthur, J. C. and Kern, F. D. North American species of Peridermium on pine. Mycologia **6**: 135. 1914.

on the basal end of the gall, whilst the swelling at the apical end of very young galls is sometimes more gradual.

Whether these distinctions are sufficiently important to separate the two forms can only be decided by inoculations. Possibly most of them may be explained by the specific influence of the host. The actual proof for the identity of the two forms is still lacking, although Arthur and Kern[13] now list *Peridermium harknessii* under *P. cerebrum.*

For all the pines growing in association with oaks, it is to be assumed that the connecting Cronartium form may still be discovered. One species of pine that does not enter into this system is *Pinus contorta*, a tree which in the Sierra Nevada inhabits higher elevations and is particularly common around and on mountain meadows. Although frequently found associated with oaks or Castanopsis, it often occurs in localities sixty to eighty miles and more from the nearest representative of either genus. The infection of *Pinus contorta* with *Peridermium harknessii* is no less common in such areas, in fact, in some localities it reaches an extraordinarily high degree. Macroscopically the fungus is identical with *Peridermium harknessii* on *Pinus radiata.* It is true, that there are data to be found in the literature regarding great distances that certain spores are able to travel without losing their faculty of infection. Klebahn[14] cites a case in which spruce plants were infected by sporidia of *Chrysomyxa Rhododendri* from Rhododendron plants over a distance of 6 kilometers (v. Tubeuf) and quotes Thaxter as follows: "although it has been shown that infection from cedars may take place at a distance of eight miles (*Gymnosporangium nidus-avis*)." In both these cases, conclusive proofs for which it would undoubtedly be difficult to bring, the small and light sporidia are said to have traveled a long distance; in our case the fungus would have to be carried, by means of the large and heavy aeciospores, from pine to oak or Castanopsis for sixty to eighty miles over mountains and flat country, more or less covered by a thick screen of forest trees, and back again the same distance by means of sporidia. In the case of *Pinus murrayana* in the Northwest this distance must be figured by hundreds of miles.

The question arises as to the means by which the fungus spreads. Either this fungus on *Pinus contorta* connects with an unknown alternate host or it is identical with the *Peridermium harknessii* of *Pinus radiata.* In this case it must be more or less independent of the supposed alternate stage on oaks or Castanopsis and its heteroecism is not obligate.

The absence of oaks and Castanopsis in many *Pinus contorta* stands, the relative rarity of *Cronartium Quercuum* on *Quercus agrifolia* even in

[13] Mycologia **6**: 133.

[14] Klebahn. Die wirtswechselnden Rostpilze. pp. 32–33.

the immediate vicinity of heavily infected *Pinus radiata* and its apparent absence on oaks and Castanopsis of the Sierra Nevada suggests the possibility that infection of what we call *Peridermium harknessii* on California pines may take place directly from pine to pine by means of aeciospores. This, of course, does not exclude the possibility of infection by sporidia, where Cronartium on oaks is present.

The idea in itself is not a new one. Eriksson,[15] in discussing the probable mode of dissemination of *Peridermium Pini*, for which no alternate host was known, came to the conclusion, without adducing any proof however, that infection must take place directly from tree to tree. Klebahn (pp. 40 and 380) on the other side considers the formation of aecia of heteroecious fungi from aeciospores or spermatia as a priori improbable. Mentioning Eriksson's failure to report a successful outcome of his direct inoculation experiments he even goes so far as to say "Es kann also hiernach auch als ziemlich sicher angenommen werden, dass eine Infektion der Kiefer mittels der Aecidiosporen nicht möglich ist." Hedgcock, according to recent personal information, has tried direct inoculation with negative results.

EXPERIMENTATION

In the following, the results of the writer's experiments are given. The aecial material used was collected on the morning of May 22, 1913 from richly sporulating galls of typical *Peridermium harknessii* on *Pinus radiata* at Sausalito, Marin County, California, where the fungus is very common, but where in spite of the most careful and continued search no Cronartium could be found on the native *Quercus agrifolia*. Other oaks or Castanopsis do not occur in the vicinity. The material was kept dry and taken at once to San Francisco, California (a distance of a few miles only). The plants used for the inoculation experiments consisted of a series of four young trees of *Pinus radiata* (3-years-old) in pots, from a reliable nursery. They were about two to two and one-half feet high, in perfect health, thrifty and without a sign of Peridermium. We will designate them as I, II, III and IV. They were kept in the laboratory, in the center of San Francisco, where contamination from the outside is out of the question and where there existed no possibility of infection through sporidia from Cronartium on oak.

On May 22 and May 23, 1913, No. I was inoculated in seven places of different ages with aeciospores suspended in water, by wounding the sprayed bark with a sterilized needle and gently rubbing the infection

[15] Eriksson, J. Einige Beobachtungen über den stammbewohnenden Kiefernblasenrost, seine Natur und Erscheinungsweise. Centralbl. Bact. II Abt. **2**: 385. 1896.

material into the wounds. Two of the wounds were left open, not bandaged. The others were wrapped in cotton and paper or protected by paper bags. The bandage was left on for a number of days. The wrapping made it necessary to cut off the bundles of needles in the neighborhood of the wounds. No. II was treated on May 23, 1913 in a number of places without wounding. The places chosen for inoculation were sprayed before and after the application of the spores. Here also the needles were cut. In other places dry spore material was dusted on after cutting the impeding needles and spraying. A sporulating gall was tied to a twig. All inoculations were protected by paper bags. All inoculated places were marked with colored twine.

III and IV were not inoculated. III was allowed to stand in a room together with I and II. IV was kept in a separate room.

A prolonged absence made regular inspections impossible. The plants, however, were sprayed regularly.

In December of 1913 several distinct oblong swellings, suggestive of *Peridermium harknessii* galls, were discovered on tree No. I on places inoculated in May. No. II also seemed to show a swelling in one place. This plant, however, soon began to decline and finally died. Immediately above the swellings on the younger parts of the living plant adventive buds began to sprout in the characteristic manner of witches'- broom formation so commonly observed above the galls of *Peridermium harknessii*. The other two plants of *Pinus radiata* remained in perfect health as did all other parts of the inoculated plant. Even No. III, which had been standing close to the infected plants for more than seven months showed no sign of infection.

During the winter of 1913–1914 the swellings, which had now become so typical that in nature one would without hesitation classify them as young galls of *Peridermium harknessii*, remained more or less stationary. No signs of pycnia or of aecia were apparent. The risk of losing the plants in the unfavorable conditions of a city laboratory made it advisable to transfer the trees to the open. On March 12, 1914 the remaining plants, Nos. I, III and IV were planted close together in the experimental garden of the Campus of the University of California, Berkeley, California. All through the year of 1914 the swellings were more or less stationary; the witches'-brooms became, if anything, a little more distinct. No signs of pycnia or aecia appeared. An inspection on March 3, 1915 brought the final result. The swellings on No. I had increased somewhat in size; the witches'-broom formation was very plain. Aecia had broken out, in each case in the very point of inoculation, indicated by a slight depression.

The photograph (figure 1) shows plainly the gall, with the aecium, and the beginning witches'-broom formation above.

The inspection of the infected trees on March 25, 1915 gave the following results:

Of the seven inoculations on tree No. I five had taken, four of which had produced well-defined aecia; two of these, on one-year twigs, produced slender barrel-shaped swellings, encircling the entire twig (one with an aecial row, about 7.5 mm. long, in the axis of the swelling; the other without an aecium, resin drops present in several places). Of the remaining three infections, one is represented by the photograph (figure 1); the swelling is of slender barrel shape. The aecium measures $1\frac{1}{2}$ by 3 mm.; the swelling itself measures 3 cm. in length by 1.2 cm. in diameter as against 0.6 cm. of the stem immediately below. Another infection caused a gall to form around about one-half of the circumference of the stem; it bears a large aecium in the center. The third infection on the lower part of the stem (at least 3 years old) resulting in a gall about three-fourths around the circumference, has a small aecium in the center. The exact ages of the stem and twigs at the various places of infection could not be determined because the plant was kept for further observations.

As to the two unsuccessful inoculations, it will be remembered that in two cases the spore material had not been protected by cotton and paper and had probably dried up.

The control plants III and IV were in perfect health without a sign of *Peridermium harknessii*. All parts of plant I not inoculated remained sound. At the present time (December, 1915) the galls have grown considerably; the check plants and all not inoculated parts of tree I are perfectly sound.

The period of incubation as figured from the time of inoculation to the first manifestation of the effect of infection, in this case, of the swelling, must be about four to five months. The first appearance of aecia in the experiments took place about twenty months after inoculation. In nature, the first swelling appears in the fall of the year of infection. During the next year the young gall remains stationary or grows but little. In the spring of the third year, the aecia develop and sporulation begins.

In the experiments the one-, two- and three-years-old stems and twigs proved susceptible to infection; none were made on twigs younger than one year, because at the time of experimentation the buds had not yet sprouted sufficiently. In nature, infection of stems older than two years must be rare, at least no infection on older stems could be found in spite of careful examination of the great number of galls. Infection of twigs during their first year of growth, on the other hand, is frequent. Investigations of this kind must, of course, be made in spring, because the result of spring infection begins to show towards fall of the same year.

Examination of the galls produced in the experiments shows that the aecia and the aeciospores are typical for *Peridermium harknessii*.

Arthur[16] records under *Cronartium Quercus* (Brondeau) Schroet. 17 to 23 by 25 to 32μ for aeciospores on non-Californian pines. Arthur and Kern[17] give 15 to 21 by 23 to 31μ for *Peridermium harknessii* and 17 to 23 by 25 to 32μ for *Peridermium cerebrum*. Later they[18] gave 15 to 24 by 23 to 33μ for *Peridermium cerebrum*, in which they now include *Peridermium harknessii*. The measurements of the aeciospores of *Peridermium harknessii* resulting from direct aecial infection in our experiments are as follows:

(148) 11 to 26μ by 19 to 41μ (standard 17 to 22 by 24 to 30μ).[19]

Fresh material of *Peridermium harknessii* collected on *Pinus radiata* at the type locality near Monterey, California, measures:

(50) 11 to 24μ by 22 to 37μ (17 to 20μ by 26 to 30μ).

For comparison with these values the following measurements of aeciospores of *Peridermium harknessii* on various hosts including the two formulas given above may be of interest:

Pinus contorta (Rocky Mountains).

(50) 15–24 x 19–43 (17–19 x 22–26)μ.
(50) 15–24 x 20–37 (19–20 x 22–26)μ.
(50) 17–26 x 19–28 (19–22 x 20–26)μ.

Pinus contorta (Sierra Nevada).

(50) 13–22 x 19–33 (17–19 x 22–24)μ.
(50) 15–26 x 20–37 (17–20 x 22–26)μ.
(50) 13–22 x 17–30 (15–19 x 22–26)μ.
(50) 11–24 x 19–35 (17–20 x 22–26)μ.
(50) 15–26 x 19–31 (19–22 x 22–26)μ.
(100) 13–30 x 19–33 (17–22 x 22–28)μ.

Pinus jeffreyi.

(40) 13–26 x 17–33 (17–20 x 20–26)μ.

Pinus ponderosa.

(40) 11–22 x 20–35 (17–22 x 26–30)μ.
(50) 15–24 x 16–37 (17–20 x 24–30)μ.

[16] North Am. Fl. **7**[2]:122.

[17] Arthur, J. C. and Kern, F. D. North American species of Peridermium. Bul. Torr. Bot. Club **33**: 421 and 423.

[18] Mycologia **6**: 134.

[19] (148) gives the number of spores measured, then follow the extreme values and finally in parenthesis the standard values. See Meinecke, E. P., Spore measurements. Science, n.s., **42**: 430. 1915.

Pinus radiata.

(50) 11–24 x 22–37 (17–20 x 26–30)μ.

Pinus radiata (aecial infection).

(148) 11–26 x 19–41 (17–22 x 24–30)μ.

Pinus attenuata.

(28) 19–30 x 26–41 (20–22 x 26–30)μ.

Pinus sabiniana.

(50) 15–24 x 20–37 (17–20 x 26–30)μ.

Pinus virginiana (eastern form).

(50) 15–24 x 22–37 (19–22 x 26–31)μ.

The values for the extreme measurements in this list vary so much that a composite formula would read: 11 to 30 by 16 to 43μ. It is plain that the extremes cannot be used for comparison.

If we consider the standard values only, it appears that the widths vary very little from the values 17 to 22 μ. The lengths, however, permit us to distinguish two well-defined groups, one wth the values 22 to 26 μ and another with the values 26 to 30 μ. The slight variations from these values lie well within the unavoidable margin of error in measuring and in rounding off the figures obtained. The first group includes all the specimens on *Pinus contorta* (*murrayana* from the Rocky Mountains), *P. contorta* (Sierra Nevada), and *P. jeffreyi*, that is, high elevation forms; the second group, the material from *Pinus ponderosa*, *P. sabiniana*, and *P. radiata*, that is, forms from the middle and lower slopes of the Sierra Nevada and from the coast little above sea level. To the latter group must be added *Peridermium cerebrum* from *Pinus virginiana*. Further inoculation experiments will have to decide the question whether or not these groups actually correspond to two different fungi. Obviously too great an importance must not be accorded to spore measurements unless they are well supported by other structural and biological characters. Morphologically all the aeciospores examined resemble each other very closely. On the other hand, the remarkable regularity of standard values as shown, for instance, in nine specimens from *Pinus contorta* on the basis of five hundred measurements, suggests the usefulness of such spore measurements for purposes of identification. That our material from *Pinus contorta* has nothing to do with *Peridermium filamentosum* which is very common in the same localities, is shown by a comparison with the formula for aeciospores of the latter fungus (numerical basis 100):

(100) 17–39 x 22–78 (22–26 x 30–33)μ.

The fact that the standard values for *Peridermium cerebrum* on *Pinus virginiana* are practically the same as those for *P. harknessii* on *Pinus*

radiata, P. ponderosa, P. attenuata, and *P. sabiniana* furnishes new evidence for the assumption that the two forms on the hosts named are identical, without, of course, proving it.

FACULTATIVE HETEROECISM OF PERIDERMIUM HARKNESSII

The experiments prove that *Peridermium harknessii* is able to infect at least *Pinus radiata* directly by aeciospores, that is, with omission of the telial stage, if there is any. In other words, although it is highly probable that the fungus is heteroecious, this heteroecism must be facultative. The same is very probably true for the so-called *Peridermium harknessii* on *Pinus attenuata* and *P. contorta* and perhaps for that on the rest of the Sierra Nevada species of pines.

Haack[20] published—one year after the writer began his experiments, and, of course, independently—positively results of direct aecial inoculation of *Peridermium Pini* on *Pinus sylvestris.* His first experiments were inconclusive; he, therefore, later inoculated pines already heavily infected, reasoning that these individuals would be more susceptible to the disease. This latter procedure together with the fact that he operated entirely in the open, already infected forest, makes his otherwise valuable experiments inconclusive. The results of my inoculations of *Pinus radiata* with *Peridermium harknessii* lend a strong support to the outcome of Haack's experiments.

Like others before him, Haack suspected that wounding of the bark is a prerequisite for successful inoculation and assumes that insects are largely responsible for such injuries. Hedgcock[21] states that "in nature, young Peridermium galls are often found associated with wounds made by an insect." On older parts of the tree the fungus "may gain entrance through wounds made by birds (sapsuckers), but this hypothesis remains to be proven."

All the writer's observations go to show that insects play an important, if not a decisive, rôle at least in direct aecial infection of the fungus from pine to pine. The common presence of old wounds in connection with *Peridermium harknessii* galls and the type of distribution of the galls on the individual tree as well as on a group of trees speak against promiscuous infection from a shower of wind-borne spores. When the infection is not general, the galls are usually found only up to a certain relative height, depending on the height and crown development of the

[20] Haack. Der Kienzopf (Peridermium pini (Willd.) Kleb.) Seine Übertragung von Kiefer zu Kiefer ohne Zwischenwirt. Zeitschr. Forst- und Jagdw. **46:** 3–46. 1914.

[21] Phytopath. **1:** 132.

tree and of the group of trees of which it is a part. In one of the examples given in the introduction to this paper, only five galls out of a total of 173 were over five feet from the ground. In another case only about twenty out of 529 were found above six feet from the ground. Often they are found only on one side of the tree or the group, unevenly distributed. Since we must assume that at the time of spore dissemination all the young twigs and branches are equally susceptible to infection, a shower of spores would find equal conditions for germination and penetration of the bark, at least in a majority of twigs or branches, and the infections would be more evenly distributed over the crown. The fact that in our experiments inoculation with wounding was successful in five out of seven cases and gave only one very doubtful result in the unwounded tree which subsequently died, speaks for the intervention of insects in nature.

All other causes of wounds through which infection could take place are absent in the case of *Pinus radiata* and *P. attenuata*. The winters of their habitat are very mild; the summers too cool for sun-scorch. Lightning and hail are practically unknown.

The common occurrence of spittle-bugs (*Aphrophora* sp.) on young stems and twigs of *Pinus radiata* may have some significance. During spring, that is, at the very time when the galls of *Peridermium harknessii* are in full sporulation, the writer found them profusely at Monterey, California, throughout the very heavily infected stands. The larvae of this cercopid wound the young stem by puncturing it. Provided the spittle contains no ingredients harmful to the aeciospores caught in it, the latter would find ideal conditions for germination by being kept moist for a considerable time. When the spittle dries up they would automatically be drawn onto the fresh wound made by the insect. It is to be noted that the spittle-bugs are nearly always located on young stems and twigs which are still protected by needles. The writer's inoculations show that not only the youngest stems, but also at least three-years-old ones may be artificially infected. In nature this is rare; so are spittle-bugs on three-years-old stems.

Hedgcock and Long[22] find that the swellings of *Peridermium fusiforme* "on the three-needle pines often originate near the extremity of a branch, and, as the side branches develop, the fungus invades them, producing an enlargement of the base of each branch." *Pinus radiata* is a three-needle pine and similar enlargements of the base of each branch of a whorl are not uncommon. Spittle-bugs very often are located on the whorl at the base of the branches.

[22] Jour. Agr. Res. **2**: 248.

FACULTATIVE HETEROECISM OF CRONARTIUM QUERCUUM

Recent inspections of oaks of the infected area on the Monterey peninsula disclosed an apparent parallelism between the facultative nature of the heteroecism of *Peridermium harknessii* and that of *Cronartium Quercuum*. The relative scarcity of the latter in the immediate vicinity of the former has already been pointed out. At the time of the first observation (first half of April) no Cronartium in its telial form had developed, but uredinial sori were fairly common on young leaves and more frequent on old green ones. The leaves of *Quercus agrifolia* remain living and green on the tree throughout winter and often until late in spring. On last year's green leaves fresh urediniospores came forth more or less abundantly from the old Cronartium spots, generally in a circle immediately around the dark-brown, dead, sunken-in places occupied last year by the Cronartium. The mycelium of the fungus, therefore, evidently overwinters in the leaf and produces urediniospores in the following spring, which are able in their turn to infect the young sprouting leaves. Hedgcock[23] has successfully inoculated *Quercus lobata*, *Q. californica* and *Castanopsis chrysophylla* with urediniospores from *Quercus rubra*. It is, of course, not impossible that some of the uredinial sori on the young leaves were the results of infection from aeciospores from *Peridermium harknessii* on *Pinus radiata*. The numerical relation of these sori to the old ones, however, speaks for an infection through urediniospores rather than through aeciospores from *Peridermium harknessii*, at least early in the season. Later infection from Peridermium may become more plentiful. Inspection of the same stands in the beginning of May did not disclose an increase in sori. The sporulation (uredo) on young leaves had all but stopped. No telial stage was found. The old green leaves were still on the trees, but sporulation on these had stopped altogether.

The Cronartium on another evergreen oak, *Quercus durata*, mentioned above, seems to behave in a similar manner. Here the uredinial sori were not very numerous on last year's leaves and were distinctly rare on this year's foliage, which was about one-third developed. The sori are smaller than on *Quercus agrifolia*, but here again the old sori produced urediniospores in quantities. The urediniospores are rather large. Occasionally very small telial columns were found; it was impossible to decide whether these were the product of last year or recently formed.

This uredinial infection explains the occurrence of *Cronartim Quercuum* in apparent independence of a heavy infection of *Peridermium harknessii*.

The heteroecism of the Californian *Cronartium Quercuum* seems to be facultative as is that of *Peridermium harknessii* on *Pinus radiata*.

[23] Phytopath. **1**: 131.

SUMMARY

Although not definitely proved, it is highly probable that *Peridermium harknessii* is identical with *P. cerebrum*. In California *Peridermium harknessii* and *Cronartium Quercuum* are to a high degree independent of each other.

The so-called *Peridermium harknessii* can be transmitted directly from pine to pine by infection with aeciospores, at least on *Pinus radiata;* in nature this probably takes place through the agency of insects. The heteroecism of *Peridermium harknessii* on *Pinus radiata* is, therefore, facultative. By analogy it is highly probable that the same facultative heteroecism occurs in *Pinus contorta* and perhaps also in the other hosts of the so-called *Peridermium harknessii.*

Cronartium Quercuum overwinters on *Quercus agrifolia;* new urediniospores form in spring around the old, dead sori on old living leaves and infect the young leaves. The heteroecism of the Cronartium also is facultative.

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FUNGOUS FLORA OF TEXAS SOILS

FREDERICK C. WERKENTHIN

WITH ONE FIGURE IN THE TEXT

HISTORICAL INTRODUCTION

Although it was generally recognized that the soil contained many forms of fungi, prior to 1886 very little work seems to have been done on the fungous flora of the soil.

Adametz[1] seems to have been the first investigator who attempted seriously to isolate soil forms and to give them names and descriptions. His work not only includes names and descriptions of bacteria, yeasts, and molds found in the soil, but it also includes a discussion of the chemical processes brought about by these soil organisms.

Nikitinsky[2] isolated thirty forms of bacteria and four species of fungi: *Penicillium glaucum, Aspergillus niger, Mucor mucedo,* and *Trichothecium* sp.

The most extensive work as to the number of species isolated from the soil is that of Oudemans and Koning.[3] The isolation was carried out by Koning, while the classification of the species was made by Oudemans. They reported forty-five species from a humous soil of the Forest of Spanderswoud, near Bussum, in Holland. Of these, thirty-two were described and named as new species.

Reference may here be made to van Iterson's[4] work on soil fungi, though his results are of doubtful value because of his method of isolation, as will be seen from the following quotation: "As inoculation material one can use soil or humus, but the best results one gets, if one exposes the petri dishes to the air for twelve hours."

[1] Adametz, Leopold. Untersuchungen über die Niederen Pilze der Ackerkrume. Inaug. Diss. Leipzig: 1–78. 1886.

[2] Nikitinsky, J. Ueber die Zersetzung der Huminsubstanzen durch physikalisch-chemische Agentien und durch Mikroorganismen. Jahr. Wiss. Bot. **37**: 365–420, 4 fig. 1902.

[3] Oudemans, C. A. J. A. und Koning, C. J. Prodrome d'une flore mycologique obtenue par la culture sur gelatine préparée de la terre humeuse du Spanderswoud près de Bussum. Extr. des Archives Neerlandaises des Science, ex. et. nat. 267–298, pl. 1–41. 1902.

[4] Van Iterson, C. J. Die Zersetzung von Cellulose durch aerobe Mikroorganismen. Centbl. Bakt. u. Par., abt. 2, **11**: 689–698, pl. 1. 1904.

Much credit is due to Butler[5] for his excellent treatise on the genus Pythium. Although he refers only incidentally to soil forms, yet his work must constitute a valuable part of the literature that we are discussing because of the species he has unquestionably shown to be soil organisms. He isolated six species of the genus Pythium.

Hagem[6] examined different soils, such as arable, meadow, garden, and forest soil for Mucorales, and isolated sixteen species of this order.

In 1908, Lendner[7] published the results of his study of the distribution, culture and classification of the Mucorales. Nine species were isolated.

In 1910, Hagem[8] published two papers on the Mucorales. Of interest to us in this connection is a chapter in his second paper in which a general discussion is given of the distribution of these fungi in various soils. In his conclusion he says: "The composition of the flora of Mucorales differs with the character of the soil. The Mucorales of cultivated soil differ very much from those of forest soil, and consist of new species entirely. The optimum temperature for Mucorales seems to lie between 20°-25°C." The first paper deals with descriptions of species isolated.

Namyslowski[9] isolated *Zygorrhynchus Vuilleminii* Namy., *Mucor microsporus* Namy., and *Rhizopus arrhizus* Fischer from the soil.

In 1911, Beckwith[10] isolated from wheat soils of North Dakota, eleven species from nine genera of imperfect fungi.

Jensen[11] in a discussion of obligate saprophytes has attempted to make a monograph of all those species of fungi that have been thus far isolated from or found in the soil. His investigations were restricted to a study of the fungi of arable soil. The first three samples, *A*, *B*, *C*, were taken in July, August, and September from an oat field near the Agricultural College at Ithaca, New York. Sample *D* was taken in October from a

[5] Butler, E. J. An account of the genus Pythium and some Chytridiaceae. Mem. Dept. Agr. India, Bot. Ser. 5, **1**: 1–160, pl. 10. 1907.

[6] Hagem, Oscar. Untersuchugen über Norwegische Mucorineen I. Videnskabs-Selskabets Skriften I. Math.-Naturv. Klasse, no. 7: 1–50. 1908.

[7] Lendner, Alfred. Les Mucorinees de la Suisse. Berne. 1–180. 1908.

[8] Hagem, Oscar. Neue Untersuchungen ueber Norwegische Mucorineen. Ann. Mycol. **8**: 265–279. 1910.

—— Untersuchungen ueber Norwegische Mucorineen II. Videnskabs-Selskabets Skriften I. Math.-Naturv. Klasse, no. 4: 1–152. 1910.

—— Einige Beobachtungen ueber die Verbreitung der Actinomycetes in der Natur. Videnskabs-Selskabets Skriften I. Math.-Naturv. Klasse no. 7: 202. 1910.

[9] Namyslowski, B. Zygorrhynchus Vuilleminii une novelle Mucorineen Isolee du sol et cultivee. Ann. Myc. **8**: 152–155. 1910.

[10] Beckwith, T. D. Root and culm infections of wheat by soil fungi in North Dakota. Phytopath. **1**: 170–176. 1911.

[11] Jensen, C. N. Fungous flora of the soil. Cornell University, Agr. Exp. Sta. Bul. 315: 415–501. 1912.

barrel of soil shipped from East Hampton, Long Island, New York. The soil was a sandy loam and, in 1910, had grown a crop of potatoes. The harvest had been small on account of disease caused by *Oospora scabies* Thaxter, *Corticium vagum* B & C., var., *Solani* Burt, and *Fusarium oxysporum* Schlecht. None of these three fungi, however, were isolated from the Long Island soil. Samples *E*, *F*, *G*, *H* and *I* were taken from the plant-breeding experimental garden east of New York State College of Agriculture at Ithaca, New York. Samples *J*, *K*, *L*, *M*, *N*, and *O* were taken from a potato field near Atlanta, New York.

In his conclusion he says: "More should be known of those fungi generally recognized as facultative parasites. Are not some of the species carried over from year to year on or in the seed, or do they live as saprophytes in the soil during the winter? Too often it is said without the proper evidence that a fungus is a soil organism. It seems to the writer that if a more detailed and far-reaching study were made of this phase of the question, it would be far more renumerative in many instances than the study of the control alone, after fungi have made a sick soil."

In the same year, 1912, Miss Elizabeth Dale[12] published a paper on soil fungi. Two samples of a light and sandy soil were taken from adjacent plots on the Royal Agricultural Society's Farm at Woburn, England. In all, over thirty-five species were obtained, some from both samples, others from only one. Twenty-two were found in plot *A*, and only thirteen in plot *B*.

Bolly's[13] experiments and observations in regard to the relation of root and soil diseases to wheat cropping have led him to believe that "sick soils" are due to fungi. In his discussion he says: "These experiments show clearly that certain species or strains of Fusarium, Helminthosporium, Alternaria, Macrosporium, Colletotrichum, and Cephalothecium are directly capable of destroying or attacking growing plants of wheat, oats, barley, bromegrass, and quack-grass." Studies were made in pots and plots upon the fungus and bacterial flora of wheat-sick soil as influenced by special methods of fertilizing. Certain methods of fertilizing and purifying such soil really influence the growth of the fungi in the soil, yet he found no soil condition in which wheat can thrive, in which the root fungi may not also persist in sufficient quantities to injure the crop. "The disease producing fungi are seldom absent from any single piece of land."

[12] Dale, Elizabeth. On the fungi of the soil. I. Sandy soil. Ann. Mycol. **10:** 452–477, pl. 9–14. 1912.

[13] Bolley, H. L. Wheat: Soil troubles and seed deteriorations. North Dakota Agr. Exp. Sta. Bul. 107: 1–94. 1913.

Goddard[14] while investigating the question of the assimilation of nitrogen by soil fungi, isolated nineteen species from a garden plot of rather rich clay loam at Ann Arbor, Michigan. In his summary of results he says: "Many species of fungi live habitually in the soil, carrying out their life history there, either in whole or in part. A considerable number of these have been found, so far, only in the soil. These fungi are, at least to quite an extent, uniform in different soils, and, unlike the bacteria, appear to be rather uniformly distributed at different depths, at least as low as 14 cm."

Miss Dale's[15] earlier work was continued by an examination of the fungous flora of three other samples of soil. Twenty-nine species were isolated from "chalky soil," twenty species from "Peat," and eighteen species were taken from "Black Earth."

PRESENT INVESTIGATION

Selection of plots. The present investigation was restricted to a study of fungi from three different kinds of soil. Samples *B*, *E*, *G*, *I*, and *M* were taken in October, November, January, and February from a cotton field on the Fiskville Road, three miles north of Austin, Texas. The crop had been gathered before the first sample was taken, and the field was left unplowed until February. At that time the dead cotton plants were plowed under. The soil of this field, according to the Bureau of Soils of the United States Department of Agriculture, is "Austin Clay."[16] The soil is derived from the weathering of a soft limestone formation, known as Austin chalk. The soil to an average depth of ten inches is a dark brown to black loam, containing a large percentage of silt and clay. Small particles of partially disintegrated limestone are usually present on the surface and in the soil.

Samples *A*, *D*, and *L* were taken in October, November, and February from flower beds of the University greenhouse. The soil had been richly manured, and geranium and other greenhouse plants had been planted the year before.

Samples *C*, *F*, *H*, and *K* were taken in October, December, January and February from the University Campus. An unfrequented place, which had lain undisturbed for at least twenty years was selected. Scanty

[14] Goddard, H. N. Can fungi living in agricultural soil assimilate free nitrogen. Bot. Gaz. **56**: 249–305, figs. 1–18. 1913.

[15] Dale, Elizabeth. On the fungi of the soil. II. Ann. Mycol. **12**: 33–62, pl. 1–5. 1914.

[16] Magnum, A. W. and Belden, H. L. Soil survey of the Austin area, Texas. U. S. Dept. Agr., Bureau of Soils; Field operations of the Bureau of Soils, Sixth Rept., 421–446. 1904.

grass had grown on the plot for several years, but no external organic matter had been added to the plot except that which had been blown upon it by winds or washed upon it by rains. The soil on this plot is also "Austin Clay." The soil is shallow, the limestone being only six to seven inches below the surface. It is comprised to a great extent of partly disintegrated limestone.

Culture media. The following media were given a thorough trial for the isolation of soil fungi: Soil extract agar, agar-agar, glucose agar, potato decoction agar, gelatin agar, raisin extract agar, bean decoction agar, carrot decoction agar, beer wort agar, and prune decoction agar.

The "soil extract" agar, as used by Jensen, was without question far superior to all media tried for isolation. The formula for this medium is as follows:

Distilled water	800 cc.
Soil extract	200 cc.
Dextrose	10.0 grams
Dipotassium phosphate (K_2HPO_4)	0.5 gram
Magnesium sulphate ($MgSO_4$)	0.2 gram
Agar-agar	15.0 grams

The "gelatin" agar, used with such success by Goddard, proved to be a failure for the present investigation on account of the tendency toward liquefaction. Miss Dale's raisin extract agar also did not work out as successfully as expected, and was abandoned after several trials.

For the pure culture tubes, all of the above mentioned media as well as bean pods, carrot plugs, and Raulin's culture fluid, were used.—Naturally no one medium was uniformly satisfactory in causing the fungi to fruit. Mucor species seemed to grow best on bean pods; while species of Aspergillus grew more luxuriantly on glucose agar, beer wort agar, and carrot plugs. Miss Dale's method of keeping the stock cultures on sterile carrot plugs seemed to be very satisfactory in the present investigation.

Method of taking soil samples. All samples were obtained by the same method. The instrument for taking the samples was built with slight modifications after the sampler used by Goddard. The sampler consists of a brass tube, three-fourths of an inch inside diameter and seven inches long. An iron rod, operating as a piston, was fitted inside the tube. At the top end of the tube, a collar was attached through which operated a small thumb screw for holding the rod in any position desired. The opposite end was sharpened for entering the soil. The iron rod was graduated so as to indicate the size of each soil sample in inches. At the top, the iron rod was rounded to form a convenient knob for holding. A view of the sampler is given in figure 1.

The samples were taken as follows: The sampler, having been set for the depth of the sample desired, was sterilized by means of dipping it several times in a solution of 95 per cent alcohol. After removing the very topmost layer of soil with a sterile scalpel, the sampler was inserted into the soil by a rotary motion. Samples were taken from one to seven inches below the surface to study the distribution of fungi according to depth. With a sterile scalpel a part of the sample, about one or two grams, was transferred to a sterile, cotton-stoppered tube containing 10 cubic centimeters of bouillon. The tubes containing the inoculated bouillon were taken to the laboratory.

FIG. 1. Soil sampler used in the investigations.

Method of isolation. Each sample was thoroughly shaken, and as soon as the coarser soil particles had settled, five loopsful were transferred by means of a sterile platinum needle, to the first of a series of two tubes, each containing ten cubic centimeters of soil extract agar which had been melted previously and cooled to 43°C. From tube 1, five loopsful were transferred to the second. Plates were then poured in the usual way. During the winter months the plates were incubated at 27°C. for forty-eight hours. After two days incubation, bacteria showed up in great abundance. But, a day or two later the fungi had outgrown the bacteria, and isolations could be made easily. Pure cultures were obtained in this way, but sometimes dilution plates were poured to separate a mixture of soil fungi. In a few instances soil samples, transferred to a sterile, cotton-stoppered test tube, were taken to the laboratory, and fungi were isolated by the planted plate method, used by other investigators. Small masses of soil that could be taken on the point of a sterile scalpel were taken from the tube and planted in petri dishes containing soil agar. By this method some of the rapidly growing fungi will crowd out the slower-growing organisms.

List of fungi isolated. Sample A. October 6, 1914. *Rhizopus nigricans* Ehrenberg, *Mucor racemosus* Fresenius, *Aspergillus ochraceus* Wilhelm, *Aspergillus niger* van Tiegh., *Aspergillus* sp. (no. 5), *Ramularia magnusiana* (Sacc.) Lindau.

Sample B. October 13, 1914. *Aspergillus niger* van Tiegh., *Fusarium Solani* (Martii) App. & Wr., *Cladosporium herbarum* Pers., *Aspergillus ochraceus* Wilhelm.

Sample C. October 29, 1914. *Aspergillus ochraceus* Wilhelm, *Aspergillus* sp. (no. 5), *Aspergillus* sp., resembling the albus-candidus-okazakii

group, *Fusarium Solani* (Martii) App. & Wr., *Fusarium oxysporum* Schlecht, *Mucor racemosus* Fresenius.

Sample D. November 4, 1914. *Penicillium* sp., variety of *P. luteum* Zukal, *Aspergillus niger* van Tiegh., *Aspergillus fumigatus* Fres. *Aspergillus ochraceus* Wilhelm.

Sample E. November 17, 1914. *Aspergillus niger* van Tiegh., *Aspergillus ochraceus* Wilhelm, *Cladosporium herbarum* Pers., *Ramularia magnusiana* (Sacc.) Lindau, *Fusarium Solani* (Mart.) App. & Wr.

Sample F. December 15, 1914. *Aspergillus venetus* Massal., *Aspergillus* sp. (no. 5); *Fusarium Solani* (Mart.) App. & Wr., *Fusarium oxysporum* Schlecht.

Sample G. January 5, 1915. *Aspergillus ochraceus* Wilhelm, *Aspergillus niger* van Tiegh., *Rhizopus nigricans* Ehrenberg.

Sample H. January 21, 1915. *Aspergillus* sp., resembling the albus-candidus-okazakii group, *Aspergillus fumigatus* Fres., *Fusarium radicicola* Wollenweber, *Fusarium Solani* (Martii.) App. & Wr., *Basisporium* sp.

Sample I. January 28, 1915. *Rhizopus nigricans* Ehrenberg, *Aspergillus niger* van Tiegh., *Aspergillus ochraceus* Wilhelm, *Aspergillus venatus* Massal, *Fusarium oxysporum* Schlecht, *Fusarium radicicola* Wollenweber.

Samples *I 4* and *I 5* were taken at depths of one and two inches below the bottom of a four inch furrow, the total depth being therefore five and six inches. From these samples no fungi were isolated.

Sample K. February 9, 1915. *Aspergillus* sp. resembling the albus-candidus-okazakii group; *Mucor racemosus* Fresenius, *Aspergillus niger* van Tiegh., *Cladosporium herbarum* Pers.; *Ramularia magnusiana* (Sacc.) Lindau.

Sample L. February 9, 1915. *Aspergillus niger* van Tiegh., *Aspergillus ochraceus* Wilhelm, *Mucor racemosus* Fresenius, *Rhizopus nigricans* Ehrenberg, *Ramularia magnusiana* (Sacc.) Lindau, *Aspergillus fumigatus* Fres., *Penicillium* sp.

Sample M. February 10, 1915. *Aspergillus niger* van Tiegh., *Aspergillus* sp. resembling the albus-candidus-okazakii group, *Aspergillus fumigatus* Fres., *Aspergillus venatus* Massal, *Basisporium* sp.

Samples M *4* and M *5* were taken at depths of one and two inches below the bottom of a four inch furrow, the total depth being therefore five and six inches. No sign of fungus growth could be found in the plates poured from these samples.

These fungi, after isolation, were studied with reference to the following points: (1) distribution as to depth; (2) distribution as to kind of soil and frequency of appearance; and (3) structural characters and identification. These will be considered in the order given.

Distribution as to depth. The studies of distribution according to

depth were made on all three plots previously indicated. Samples were taken at six different depths: one inch, two inches, three inches, four inches, five inches, and six inches.

The number of colonies appearing in each sample was counted and the average percentage for each depth determined.

The average for twelve samples is as follows: One inch, 25 per cent; two inches, 30 per cent; three inches, 30 per cent; four inches, 15 per cent; five inches and six inches, none. The comparative results indicate that the fungi of the soil were distributed rather uniformly at depths from one to three inches. No fungi appeared at a depth of five or six inches. These results seem to coincide with those of Goddard.

Distribution as to kind of soil. As previously stated, the three plots were different as to the kind of soil, tillage, and fertilization. A marked difference was expected in the flora of the different plots, especially in plot I as compared with plot II. The soil of plot I was cultivated soil, while the soil of plot II had remained untouched for at least twenty years. Almost all fungi isolated from plot I were also isolated from plot II. Out of about 150 isolations, representing fifteen different species but one species was found exclusively on plot I, while two species were found exclusively on plot II. Five species found in plot I and plot II were not found in plot III. One species (Penicillium) was only found in plot III. A summary of the results is given in table 1.

TABLE 1

Summary of isolations of fungi from different plots of soil

PLOT I	PLOT II	PLOT III
Fungi isolated from cotton field	Fungi isolated from University Campus	Fungi isolated from University greenhouse
Aspergillus niger	Aspergillus niger	Aspergillus niger
A. ochraceus	A. ochraceus	A. ochraceus
A. venetus	A. venetus	.....
.....	A. sp. (No. 5)	A. sp. (No. 5)
A. sp., (albus-candidus-okazakii group)	A. sp. (albus-candidus-okazakii group)	.....
A. fumigatus	A. fumigatus	A. fumigatus
Fusarium Solani	Fusarium Solani	.....
F. oxysporum	F. oxysporum	.....
F. radicicola	F. radicicola	.....
Ramularia magnusiana	Ramularia magnusiana	Ramularia magnusiana
Cladosporium herbarum	Cladosporium herbarum	Cladosporium herbarum
Rhizopus nigricans	.....	Rhizopus nigricans
Basisporium sp.	Basisporium sp.	.....
.....	Mucor racemosus	Mucor racemosus
.....	.....	Penicillium sp.

In order to show the frequency of the occurrence of the genera and species in the soils investigated a table has been worked out (table 2).

TABLE 2

List of fungi arranged according to the frequency of appearance in soil samples

NAME OF FUNGUS	TOTAL NUMBER OF APPEARANCES
Aspergillus niger	30
Aspergillus ochraceus	28
Aspergillus sp. (No. 5)	18
Aspergillus venetus	15
Aspergillus sp. (albus-candidus-okazakii group)	12
Aspergillus fumigatus	12
Cladosporium herbarum	8
Rhizopus nigricans	6
Mucor racemosus	5
Fusarium Solani	5
Ramularia magnusiana	5
Fusarium radicicola	4
Basisporium sp	4
Fusarium oxysporum	3
Penicillium sp	2

LIST OF FUNGI OBTAINED FROM SAMPLES

The species are arranged according to the classification adopted by Engler and Prantl.[17]

Mucor racemosus Fresenius. Isolated from sandy and loamy arable soils, Germany, by Adametz; from sandy, loamy soil from potato field, Long Island, N. Y., by Jensen; from sandy soil from a plot on the Royal Agricultural Society's Farm at Woburn, England; from chalky soil from the Gog Magog Hills near Cambridge, England; and also from "black earth" from a farm near Ely, England, by Miss Dale; from Texas soils five times by the author.

Rhizopus nigricans Ehrenberg. Isolated from soil, Norway, by Hagem; from soils, Germany, by Adametz; from plant breeding plots near Cornell University during the winter 1910–1911, by Jensen; and also isolated six times by the author from Texas soils during 1914–1915.

Aspergillus niger van Tiegh. Isolated from sandy soil from a plot near the Royal Agricultural Society's Farm at Woburn, England, by Miss Dale; also isolated thirty times from Texas soils by the author.

[17] Engler and Prantl. Natürlichen Pflanzenfamilien. 1897.

Aspergillus ochraceus Wilhelm. Isolated twenty-eight times from Texas soils by the author, who is indebted to Dr. Charles Thom for the determination of this fungus.

Aspergillus sp. (no. 5). Dr. Thom states in a letter that he has a description and figures of this species, but is not as yet satisfied to offer a name.

Colonies light brown at first, later chocolate brown. Sterile hyphae 2 microns thick. Conidiophores 3 to 5 microns in diameter, of light brown color. Conidial heads brown, 14.5 to 15 microns in diameter. Sterigmata branched, on all sides, primary 4.5 to 5 microns long, 3 microns in diameter, secondary 4 microns long, 2 microns in diameter. Conidia spherical with rough surface, 2.2 to 2.5 microns in diameter, of light green color.

Very common in Texas soils. Isolated eighteen times by the author.

Aspergillus venetus Mossal. Isolated from Texas soils fifteen times by the author.

Aspergillus sp. resembling the albus-candidus-akazakii group. Colonies white. Conidiophore 2 to 4 microns in diameter, colorless. Condial heads white, small, 12 to 14 microns in diameter. Sterigmata not branched, 5 to 7 microns long, 2.5 microns in diameter. Conidia very numerous, 2 to 3 microns in diameter, spherical, almost colorless.

This Aspergillus produces asci on Beerwort agar. The asci are 2.6 by 5 microns and contain from six to eight ascospores, 1 by 1.5 microns.

Found in twelve samples taken from Texas soils by the author, who is indebted to Dr. Charles Thom for the identification of this fungus.

Aspergillus fumigatus Fres. This Aspergillus is apparently the same as *Aspergillus* sp. No. 7, isolated by Miss Dale from sandy soil. The colonies are at first white, but in a few days the center turns yellowish green and the edges take a dark shading. After ten to fourteen days the center changes its color again and turns deep yellow to yellowish green, surrounded by a zone of yellowish cream color. Conidial heads almost colorless, 15 microns in diameter. Sterigmata not branched, 4 to 6 microns long, 2 to 3 microns in diameter. Conidia numerous, 2 microns in diameter, spherical, yellowish in color.

Isolated twelve times from Texas soils by the author, who is indebted to Dr. Charles Thom for the identification of this fungus.

Penicillium sp., var. of *Penicillium luteum* Zukal. Conidiophores a thin and incomplete layer, scantily produced mostly as lateral branches of aerial hyphae, 20 to 100 microns (mostly 30 to 45 microns) by 3 microns. Conidial heads usually small, up to 80 microns in length, commonly with a single lateral branch and but two verticils of long acuminate basidia 13 to 16 by 3 to 4 microns; rather firm walled, greenish. Isolated only twice from Texas soils by the author.

Dr. Thom says that these species differ in details of reaction and general appearance of colony, but harmonize in certain essential structures and reactions to such a degree that he hardly dares to separate the various races found.

Cladosporium herbarum (Pers.) Link. Isolated by Miss Dale, from sandy soil, chalk, and uncultivated mountain peat. Common in Texas. Isolated eight times by the author.

Basisporium sp. The young colonies form a very characteristic radiating silky mass of branching hyphae, shining and white. The mycelium is colorless, septate, and branched, 1 to 1.5 microns in diameter, bearing at intervals along its hyphae the roundish brown spores with a light center (oil spots). The spores are 3.5 by 4.8 microns.

Isolated four times from Texas soils by the author. Still pending identification from Dr. Thom.

Fusarium radicicola Wollenweber. Found on partly decaying tubers and roots of plants, such as *Solanum tuberosum* in Europe and America (collected by Wollenweber[18]) and *Ipomoea batatas* in the United States of America (collected by Harter and Field). Also found as inhabitant of the soil in Texas (isolated four times by the author).

The author is indebted to Dr. Carpenter for this determination.

Fusarium Solani (Mart.) App. & Wr. Saprophyte common on potatoes and various other hosts both in Europe and America. Isolated from sandy soil from a plot on the Royal Agricultural Society's Farm at Woburn, England, by Miss Dale, and five times from Texas by the author, who is indebted to Dr. Carpenter for this determination.

Fusarium oxysporum Schlecht. Isolated from Texas soils three times by the author, who is indebted to Dr. Carpenter for the determination of this fungus.

Ramularia magnusiana (Sacc.) Lindau. Found in Germany in humus, Dahlem, March, 1911; isolated from Texas soils five times by the author, who is indebted to Dr. Carpenter for the determination of this organism.

DISCUSSION

It will be seen from the foregoing that cultivation of soils does not seem to change the flora of soil fungi. The samples taken from the cot-

[18] Wollenweber, H. W. Studies on the Fusarium problem. Phytopath. **3**: 24–50, 5 pls. 1913.

—— Ramularia, Mycosphaerella, Nectria, Calonectria. Eine Morphologisch-Pathologische Studie zur Abgrenzung von Pilzgruppen mit Cylindrischen und Sichelförmigen Konidienformen. Phytopath. **3**: 197–242, pl. 20–22. 1913.

—— Identification of species of Fusarium occurring on the sweet potato, Ipomoea batatas. Jour. Agr. Research **2**: 251–285. 1914.

ton field yielded, with two exceptions only, the same kind of fungi as did the samples taken from the University campus. Hagem's statement, that "the Mucorales of cultivated soil differ very much from those of forest soil and consist entirely of new species," does not hold true for the present investigation as shown in table 1.

Of special interest in the study of soil fungi is the fact that the virgin soil contained fungi which are known to be parasitic to cultivated plants, e.g., *Fusarium Solani* (Mart.) Sacc., *Fusarium oxysporum* Schlecht, and *Fusarium radicicola* Wollenweber. It also should be noted that these fungi were isolated several times from the same plot during a period of over five months, which fact should show clearly that these fungi are true inhabitants of the soil. These data give a satisfactory answer for these species to Jensen's question: "Are not some of the species carried over from year to year on or in the seed, or do they live as saprophytes in the soil during the winter?" The present investigation proves clearly that these fungi live as saprophytes in the soil at least through the winter months, and it seems reasonable to assume that they must live saprophytically throughout the year.

In regard to the depth it must be said that the fungous flora was almost the same for depths ranging from one to four inches. This fact coincides with the results of Adametz, who found the same species indifferently in the shallower or deeper levels. Some study was also made by Goddard in regard to the depths at which particular fungi were found. He says: "Any particular species seemed about as abundant at one depth as at another, down as deep as samples were taken."

The foregoing results would indicate that there is a rather constant and characteristic fungous flora in the soil. The dominant type in Texas seems to be species of Aspergillus, while species of Mucor and Penicillium occur only occasionally. Species of Aspergillus occurred one hundred and fifteen times in the plates taken from Texas soils, while species of Mucor were isolated only five times, and Penicillium but twice. According to Hagem, the optimum temperature for the Mucorales lies between 20 and 25°C. The present investigation seems to show that species of Aspergillus studied have a decidedly higher optimum temperature than species either of the Mucorales or of Penicillium. At incubator temperature (27°C.) all of the species of Aspergillus isolated showed a much more rapid and vigorous growth than those of the Mucorales or Penicillium. The optimum temperature of these Aspergilli probably reaches 30°C.

The total number of the most abundant species isolated by Jensen, Goddard, and the author are given in the following table:

NAME OF INVESTIGATOR	TOTAL NUMBER OF ISOLATIONS FROM A SPECIES OF			
	Aspergillus	Penicillium	Mucor	Fusarium
Jensen	5	14	5	3
Goddard	—*	—*	14	13
Author	30	1	5	5

* The total number is not given.

From this table it appears that in northern climates the dominant soil fungi seem to be species of Penicillium, while in the South, species of Aspergillus are the leading type.

SUMMARY OF RESULTS

1. Up to the depth of four inches, soil fungi are fairly uniformly distributed. In deeper regions, below four inches, no viable fungous spores seem to be present.

2. There does not seem to be any variation of fungi in regard to cultivated or virgin soil.

3. The climate seems to have great influence on the flora of soil fungi. Species of Aspergillus are the dominant soil fungi of the South; Penicillii, so frequently found in northern states, are rare in Texas soils; the Mucorales are not as abundant in southern soils as they are in colder climates.

4. Pathogenic fungi, especially species of Fusarium, live in the soil as saprophytes throughout the winter.

This work has been directed by Dr. Fred McAllister, whose kindly assistance, helpful suggestions, and criticisms have greatly aided and encouraged the work. The writer also takes pleasure in expressing his sincere thanks to Dr. Charles Thom, Dr. C. W. Carpenter, and Dr. A. F. Blakeslee for their kind assistance given in the identification of fungi.

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A WILT DISEASE OF THE COLUMBINE

J. J. TAUBENHAUS[1]

WITH TWO FIGURES IN THE TEXT

In the summer of 1913, the writer's attention was attracted to a serious disease of the garden columbine, *Delphinium* sp. The disease was so severe as to practically destroy the entire planting. An examination of the diseased plants showed them plainly to be affected by the fungus *Sclerotinia libertiana* Fckl. A search through the literature failed to show any record of a Sclerotinial disease that affects the columbine. This host is of economic importance to the florists and gardeners, in-so-far as it is grown and sold as an ornamental plant.

The disease is characterized by a general wilting of the leaflets and tender shoots, accompanied by a slow drying of the affected branches. Usually the disease progresses slowly, affecting one by one the main branches of the plant (fig. 1). The roots of the plants are not attacked by the fungus and frequently during periods of prolonged dry weather badly diseased plants may recover. On the other hand, with continued rainfall the roots of diseased plants may die from the attacks. A close examination of newly infected plants shows the presence of a webwork of white fungus strands on the diseased stems. These hyphae penetrate deeply into the interior, and the freshly invaded tissues appear water-soaked. In splitting lengthwise an infected stem, the hollow interior is seen to be filled with white fungus hyphae and numerous sclerotia in various stages of formation. The sclerotia are about three to four millimeters in diameter and in stems killed by the fungus the numerous hard, black sclerotia practically fill the center of the dead stem (fig. 2, a and b). In appearance, these sclerotia resembled those of *Sclerotinia libertiana* Fckl.

Four young, healthy columbine plants were planted in pots and kept in the greenhouse for four weeks, in order to make sure of the absence of any disease. Previous to the time of inoculation, the four plants were covered with bell glasses for about twelve hours, in order to create a saturated atmosphere. Two of the plants were then inoculated with a pure culture of the fungus, which had been isolated previously from a diseased columbine plant growing in the field. The fungus was grown in a tube of potato agar, and the entire contents of the tube was placed at the foot of

[1] Formerly of the Delaware Experiment Station where this work was performed.

the inoculated plants. The other two plants were not inoculated and served as checks. The bell glasses were removed from the four plants twenty hours after inoculation. After about two days the inoculated plants showed a wilted appearance and were affected at the base of the stem. The symptoms of the disease were characteristic of the affected plants found in the field. The fungus was easily reisolated and the Sclero-

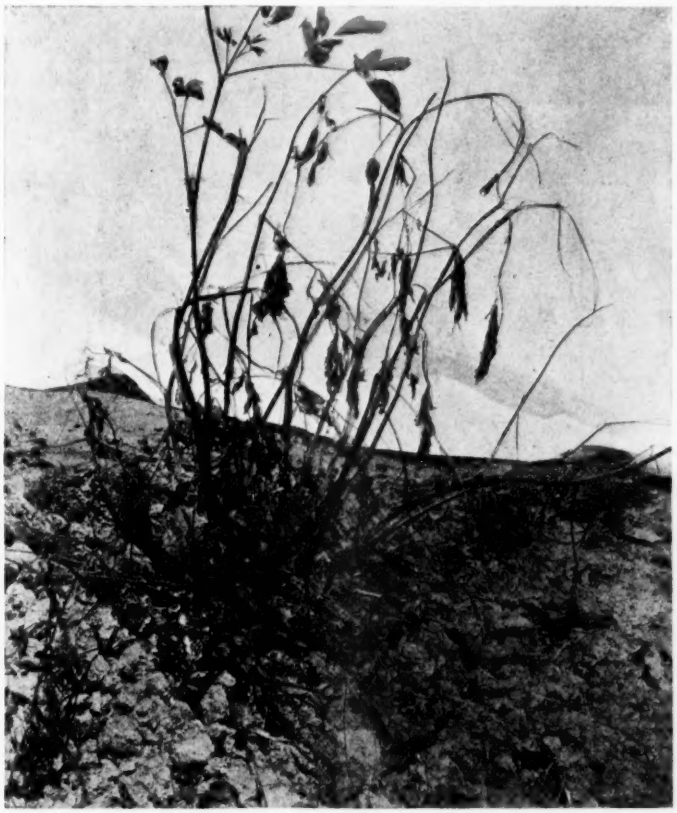

FIG. 1. Columbine plant partly killed by the wilt fungus.

tinial growth was again the dominant feature. This proved that the Sclerotinia-like fungus is the cause of the columbine wilt. Attempts were made later to inoculate the two healthy check plants with a pure culture of the above Sclerotinial fungus; but the plants were not covered with bell glasses and infection failed to take place. This indicates that moisture is an important factor in enabling the fungus to attack the host plant.

In order to determine the identity of the fungus, numerous sclerotia were collected from dead vines and from pure cultures. The sclerotia were buried to a slight depth in pots of sand and exposed to the weather throughout the winter. Early the following spring, the sclerotia from both dead vines and from pure cultures were found to germinate and to

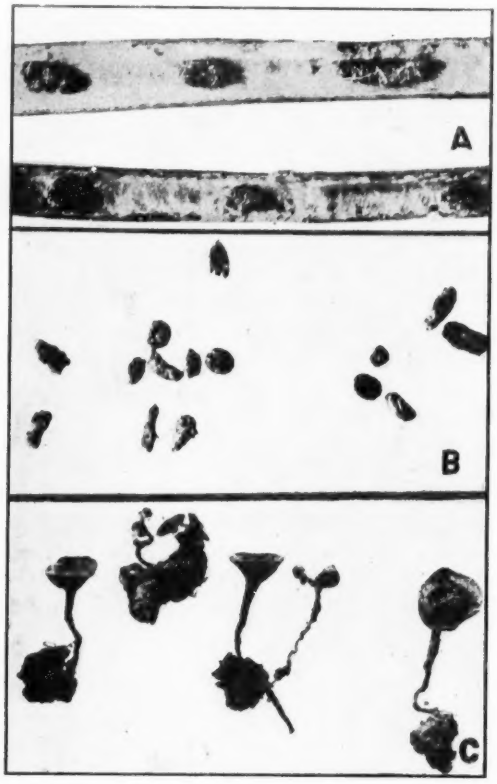

FIG. 2. Sclerotia and apothecia of Sclerotinia libertiana. *A*, dead stem split longitudinally to show sclerotia; *B*, sclerotia; *C*, germinated sclerotia of Sclerotinia libertiana, taken from dead columbine vines.

produce apothecia (fig. 2, c). In measurement of asci and ascospores, as well as in other characteristics, the fungus was found to be identical with *Sclerotinia libertiana* Fckl. Ascospores from the germinated sclerotia when placed on nutrient agar produced a growth typical of *S. libertiana*, so that there could no longer be any doubt as to the specific position of the fungus.

Sclerotinia libertiana on the columbine may winter over as sclerotia in manure which is often used as a mulch. In fact, the disease was found to originate in the columbine planting of the Delaware Agricultural Experiment Station garden where manure was used as a mulch.

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COLLEGE STATION, TEXAS

SOME NEW STRAWBERRY FUNGI[1]

F. L. Stevens and Alvah Peterson

SPHÆRONÆMELLA FRAGARIÆ AS THE CAUSE OF A STRAWBERRY ROT

Berries affected with the Sphæronæmella rot disease shrink, lose their normal color and soon become covered with the gelatinous, glistening pycnidia of the fungus. This disease was first noticed in Louisiana in 1914. Later it was found on berries in the markets at Urbana where it was so common that of the boxes brought to the laboratory a large proportion of the berries developed the disease. It was again observed both in Louisiana and in the Urbana markets in 1915. It is not primarily of great significance since its development is not very rapid. In the case of berries which receive a ready sale it probably is of little consequence. The disease is, however, of significance since through its lesions more destructive fungi e.g. Rhizopus, can enter.

Berries affected with this disease do not show a definitely limited spot either superficially or in section. The affected area becomes tan colored, the berry shrivels and within a few days the whole berry is affected. The surface of the berry becomes closely studded with the tan- to dark-colored pycnidia. These, due to their peculiar gelatinous texture, give to the affected berries a characteristic feeling so that the disease may usually be recognized by this character alone. Section of a diseased berry shows the interior discolored (tan), moist but not excessively wet or soft.

The mycelium completely occupies the tissue below the pycnidia and produces a spongy texture. The mycelial threads are hyaline and vary in diameter from coarse, 7 μ, to fine, 1.5 μ. They are frequently septate with many of the old cells empty. Strands often taper rapidly from the coarse to the fine form. Branches are often at right angles. The filaments are usually nearly full of spherical highly refractive droplets.

The pycnidia originate as mycelial knots below the epidermis and develop to considerable extent subepidermally. They finally become erumpent and are at first tan-colored, but often, though not always, assume a blackish external tint as they age. The sporiferous part is spherical about 500 to 700 μ in diameter, normally simple but sometimes lobed and chambered. The rostrum is about 300 μ long above the pycnid-

[1] A brief statement concerning these fungi was made in Science **41**: 912. 1915.

ium and about 150 μ thick. When wet the rostrum in optical section exhibits a central dark region surrounded by a sheath which is translucent being composed of hyphæ that are more loosely woven and of more gelatinous texture than those in the central region. The pycnidium especially the rostrum is loosely covered with long tangled gelatinous hairs.

The spore chamber is filled with conidia borne on basal and lateral conidiophores. The conidiophores are hyaline and simple, about 2 μ thick and 15 to 17 μ long, rarely 24 μ long.

The spores are cylindrical with rounded ends, measure 0.5 to 6.5 by 1 to 1.5 μ, are continuous and hyaline.

The fungus was isolated by the following means: (1) By dilution plating of the spores. (2) By direct planting of pycnidial spores. (3) By direct planting of mycelium from the interior of a diseased berry.

The fungus grows readily on various media producing a very luxuriant, characteristic mycelium which however under many conditions fails to produce pycnidia. Thus mycelial transfers to poured plates always result in rapid growth of very dense colonies, but usually without pycnidia until the colony is very old (2 to 3 weeks). Then at the edge of the colony a few pycnidia may or may not develop. Sometimes, though rarely, such colonies later become pycnidial in their central regions. When, however, spores were thickly sown in plates so that from one hundred to two hundred colonies developed per plate, each colony bore a pycnidium at its center and often others as well.

On corn meal agar the colony was hyaline and slow-growing. Pycnidia formed first at the margin, later toward the center. The colonies were very dense, of entire but wavy margin and the surface showed a glistening satin-like appearance and a wavy structure, difficult to describe, due to large numbers of filamentous crystals of unknown composition.

On artificial media, the pycnidia often grow in clusters, several arising from the same basal prominence. Also the beaks are frequently very hairy.

Numerous inoculations were made using both the mycelium and the spores suspended in sterile water and applied with a platinum loop, either with or without injury to the cuticle of the berry. Results of inoculations were somewhat unsatisfactory since the berry could not be sterilized and since both this fungus and the species of Patellina described later, were so commonly present upon the berries used. Conclusions could therefore be drawn only from the differences between the inoculation sets and the control sets. There were, however, so many positive results of spots at the exact point of inoculation that there can be no doubt of the causal relation of the fungus to the rot.

The pycnidium of such distinctly gelatinous or waxy texture clearly places the fungus in the order Sphæropsidales, in the family Nectrioidaceæ, and in the sub-family Zythieæ. The spore characters place it in the Hyalosporæ. The family Nectrioidaceæ is singularly free from aggressive parasites. Indeed, with the exception of the genus Zythia it finds no place in economic literature.

The beaked pycnidium together with the other characters presented agree fully with Sphæronæmella in which genus the fungus belongs.

This genus contains according to Saccardo's Sylloge Fungorum some nineteen species which grow upon wood, bark, fungi, dung, ferns and herbs.

The species as described in the Sylloge Fungorum have been tabulated (table 1). They are arranged in the order of the minimum spore length and such other data are included as were available and comparable. It is seen, that allowing for reasonable variation in spore size and in the measuring of spores, only numbers six to nine and fourteen to nineteen can be considered. Of these, numbers seven, eight, sixteen and seventeen are excluded by the length of the rostrum. Number six is eliminated by comparison with an authentic specimen of the North American Fungi Collection No. 2566, because of the different shape of the spores. Numbers nine and fifteen are eliminated for the same reason. Number eighteen is eliminated by its appendiculate spores and numbers fourteen and nineteen are so meagerly described as to be unidentifiable.

The species in hand seems to be distinct from any heretofore described. We therefore describe it as:

Sphæronæmella Fragariæ n. sp.

Pycnidia erumpent, globose, 670 μ in diameter, gelatinous or waxy, tan-colored, varying to almost black in outer cells, base partially immersed, height including beak 1000 to 1100 μ, beak when dry 150 μ thick, when wet with a swollen translucent envelope, often densely hairy, especially the beak. Spores cylindrical, obtuse, straight, 5 to 6.5 by 1.5 μ. Condiophores simple, tapering, 15 to 17 to 24 by 2 μ.

Habitat. On fruit of cultivated Fragaria, Louisiana.

PATELLINA FRAGARIÆ

The disease caused by *Patellina Fragariæ* is first visible as small sunken discolored spots on the green or ripe strawberry. The areas are soon thickly set with the saucer-shaped sporodochia characteristic of the causal fungus. It was first noted on specimens collected in Louisiana in 1914; later in the same year it was observed at Urbana, Illinois, on market

berries from various sources. It was repeatedly collected from the same sources in the spring of 1915. In fact almost any box of berries, on standing a few days presented the disease, and in many cases a large percentage of the berries in a box showed the spots. That it is not merely a secondary organism appearing upon old berries is shown by the fact that it has been collected in the field upon berries still upon the vines, both upon ripe and upon green berries.

The spot upon green berries is tan-colored, somewhat sunken and en-

TABLE 1

A tabulation of the species of Sphæronæmella

NUMBER	NAME	SACCARDO		PERITHECIA		CONIDIA			HOST
		Volume	Number	Diameter	Length of rostrum	Shape	Length	Breadth	
				mm.	*mm.*		μ	μ	
1	microsperma	18	4810	1.9	3.5	spherical	0.8–1		Betula
2	mirabilis	10	6550	2.5–3	2–3	elliptical ovate	2.5–4	1–1.5	bark
3	coriariæ	11	3570		3–4	ovoid	3	1	Coriaria
4	mougeotii	3	3304			oblongalantoid	3	1	Hedera bark
5	filicina	10	6551		1	oval	3	2	Hymenophylli
6	Rosae	10	6548	0.2		elliptical	4.5–5.5	2.5–3	Rosa
7	Wentii	16	3785		9		7	4	Viciae
8	fimicola	10	6552	1.5–2.5	7–8.2	elliptical	7–7.5	2–2.5	dung
9	Helvellæ	3	3312	1.2–1.5	3–3.5	elliptical	7–13	4.6	Helvella
10	rufa	3	3308			globose	9	2.5	Pinus, Magnolis, Clethra
11	diaphana	3	3306			elliptical	12	4	Larix
12	carnea	10	6549		2	oblong	15	4	Acer
13	macrospora	18	4811		1	elliptical ovate	21–22	8–10	bark
14	acicularis	3	3305						Quercus, Pinus
15	flavo-viridis	3	3307			ovate	minute	minute	dead wood
16	cincta	3	3209		long				Pinus
17	aurantiaca	3	3310			ovoid	small	small	trunks
18	oxyspora	3	3311			elliptical appendiculate			Polyporus and Agarics
19	cucurbitula	16	3786	minute					Gomphidii
20				6.7	3	cylindrical	5–6.5	1.5	Fragaria

larges but slowly. Upon ripe berries the character of the spot is the same but its development is much more rapid. The central region of a spot which has attained a diameter of about seven to eight millimeters bears sporodochia. Two or three millimeters of the border of the spot are free from sporodochia. Cross, median sections through a spot show the affection to be deep, usually deeper than the diameter of the spot. The core of the affected host in that part is consumed and replaced by fungous my-

celium and thus presents a spongy dry texture. This core is separated from the unaffected host tissue by an intermediate zone two or three millimeters in thickness which contains no mycelium but the host, cells of which are separated from each other and are soft and wet. The softening of this part of the host is apparently due to enzymes secreted by the fungus. Owing to the presence of this softened region and to the tenacity of the central core of the spot it is possible to remove with forceps the entire affected region.

The spot develops rapidly upon a ripe berry. A spot five millimeters in diameter may enlarge to cover a whole berry in about four days.

The Fungus. Either teased or microtome preparations reveal the host cells in the affected region to be filled with the richly branching, many-septate, hyaline mycelium. The region adjacent to the dissolved layer referred to above shows only the tips of the advancing hyphae, with all of the threads arranged with their axes perpendicular to the tangent of the spot at that point. In a median section through a spot the sporodochia may be seen in all stages of development. They are of subcuticular origin and soon become erumpent. They vary in shape from columnar with a flat top to broad saucer-shaped. The external portion is sterile and constitutes a kind of peridium, a sterile rim to the disk. This rim may be narrow and even or fairly wide and wrinkled or crimped. The peridium in all specimens may assume a rusty or tan-colored appearance and its component filaments may become rather firmly agglutinated.

The central region is sporiferous and consists of myriads of parallel conidiophores presenting a nearly flat upper surface. Dissection shows the conidiophores to be much branched, never simple, with the spores borne acrogenously and apparently solitary, i.e., not catenulate. The young sporodochia may be hyaline or they may absorb the coloring matter of the ripe berry and present a true ripe-strawberry color. As they age and the spot beneath them becomes tan-colored the sporodochia undergo the same color change. As the sporodochia age they lose, to a large extent, their saucer shape though this loss is really more apparent than real and is due to a heaping up of spores in the center of the sporodochium. In age also the outer row or rows of sterilized conidiophores turn slightly brownish or tan-colored and become rather firmly agglutinated.

The spores are produced in enormous quantities and in humid air may accumulate in the tops of the sporodochia in glistening, globular, slimy drops. They are about twice as long as broad, 6.5 to 8 by 2.5 to 3.5 μ, inequilateral, with one side nearly straight or very slightly concave or convex, the other strongly convex. Both ends are sharply but abruptly pointed. They are hyaline and one-celled.

The mycelium is striking in appearance. The old threads are coarse, 7 μ in diameter, but the main part of the mycelium consists of fine, branch-

ing threads, 2 μ in diameter. The characteristic mycelium and spore-bearing structures are constant in this disease. The mycelium migrates entirely under the epidermis breaking through to form the sporodochia one or two millimeters from the invasion line of the fungus.

The sporodochia are nearly or quite sessile, are at first circular, flat-topped or a trifle saucer-shaped and with a distinct sterile rim or border.

Isolation was readily accomplished by the usual dilution plating of spores from a sporodochium as well as by direct planting of bits of mycelium upon poured agar plates. Bits of mycelium-bearing tissue taken with aseptic precautions from below the epidermis of a spot invariably gave pure cultures of the fungus.

On bean agar colonies were colorless and circular; after thirteen days they were four to five centimeters in diameter, with the mycelial growth very dense, none of it aerial; the colony border was very even, the sporodochia hyaline to tan-colored and located nearly 1 centimeter back from the margin of the colony.

Inoculations were readily made using either the mycelium or the spores in either wounded or unwounded surfaces. The following note is typical: "Inoculated in wounds on ripe berries April 23 kept in moist chamber at room temperature. On April 26 every berry showed a rotten spot at the point of inoculation and numerous sporodochia."

The following description of a four-days-old spot was made from a typical case on April 27: "Decayed spots from five to ten millimeters in diameter, slightly sunken at the center, tan-colored, verging through light pink near the border to the normal color of the ripe berry. Area throughout and to within about one to two millimeters of the border of the spot studded with sporodochia."

"Sporodochia varying in shape from round, disk-shaped, regular to saucer-shaped and irregular. In color taking the exact color of the supporting tissue so long as this has the normal strawberry color, later changing to tan."

Since it was not feasible to use sterilized berries and since the fungus was naturally so frequently present the controls did not give uniformly negative results. Indeed the controls usually give some, sometimes fairly numerous, cases of disease. The occurrence of the disease was however uniformly much higher in the inoculated berries than in the controls.

The fungus clearly falls within the Tuberculariaceæ-Mucedineæ-Amerosporeæ, and seems with equal certainty to belong to the genus Patellina. This genus, according to Saccardo's Sylloge Fungorum, contains some sixteen species apparently, in the main, saprophytes on wood, bark and so forth. Heretofore none has been reported as of economic significance.

To clarify the consideration of the question of specific position the following table (table 2), has been prepared with the species arranged in order of the minimum spore length given.

The present form, on a basis of spore length alone, can belong only to numbers six to twelve or fifteen or sixteen, and all of these except number eight are excluded on a basis of spore shape. No shape is given for the spores of number eight but if they were crescent-shaped as ours are such a striking character would doubtless have been mentioned. The fungus therefore, appears to be new and we present the following description.

Patellina Fragariæ n. sp.

Sporodochia hyaline to tan- or rose-colored, rarely columnar and flat topped to beaker-shaped, more often saucer or disk-shaped, 120 to 300 μ in diameter, about 120 μ high, surrounded by a peridium of sterile threads and the disk bordered by a sterile frill often revolute or wrinkled.

Conidiophores slender, 1 by 50 μ long, hyaline, abundantly branched, spores solitary, acrogenous.

Spores slightly crescent-shaped, acute at each end, 6.5 to 8 by 2.5 to 3.5 μ.

BOTRYTIS CINEREA

Botrytis cinerea has been observed in great abundance upon Louisiana berries in the field and upon market berries of various origin. A note concerning this disease was published by one of us.[2]

This fungus has since been observed in very destructive form.

SPHÆROPSIS MALORUM

Sphæropsis Malorum was found causing a characteristic blackening or bronzing of the berries. It appears to be of but little economic importance here.

RHIZOPUS NIGRICANS[2]

Rhizopus nigricans is the fungus which at the destination of the berry is most in evidence and the fungus which in reality does most of the damage to shipped berries. The characteristic result is a very soft, moldy berry with the juice leaking abundantly from the container. It is evi-

[2] Stevens, F. L. A destructive strawberry disease. Science, n. s. **39**: 949-950. 1914.

TABLE 2

A tabulation of the species of Patellina

NO.	NAME	SACCARDO		SPORODOCHIUM			CONIDIA				DIMENSIONS OF CONIDIOPHORES	HOST
		Vol.	No.	Shape	Color	Diam.	Shape	Ends	Length	Breadth		
						mm.			μ	μ	μ	
1	mellea.....	22	8818	orbicular or elongate		3–5	globose	rounded	1.5–2	1.5–2	60	Pinus
2	italichroma..	3	3328	orbicular-applanate			elliptical or ovoid		3–4	1.5	8–120 x 1	Melia
3	subconoidea..	22	8819	subhemispherical	black	3.5–5	elliptical	rounded	3–4	2–3	?	Phœnix
4	cinnabarina..	4	3206	patelliform	yellow	0.5	ovoid		3–4.5	2	20 x 1	Platinus
5	Ilicis.....	18	5770	orbicular	fleshy, waxy	3.5	elliptical or ovoid		3–4.5	1.5–2.6	25–50 x 1.5	Ilex
6	buellioides..	10	8047	irregular	yellow	0.5–1	subcylindrical	obtuse	4–6	1.5–2.5	20–30 x 1	lichens
7	italichroma var. Talae	4	3205	cupulate	green	0.5–0.8	elliptical	acute	5	2	30 x 1	Celtis
8	pallida.....	14	4488	orbicular or irregular	white, rose	0.5–2			5–6	2	100	bark
9	amœna.....	16	4256	applanate	red, yellow	0.5–2	cylindrical		5–7	2–3	28 x 32–23	bark
10	bicolor.....	10	8048	cupulate	white	0.1	orbicular, elliptical		5–7	2–3	20–45 x 0.5	bark
11	tropicalis....	16	4257		rose, red	1–1.5	elliptical, irregular	obtuse	5–10	3–4	15–50 x 1	
12	rhodotephra.	4	3207	orbicular irregular ovoid	white to yellow		ovoid	acute	6	3		Morus
13	pusilla.....	10	8046	globular or patelliform	white, hyaline to dirty	3.2–3.5	bacilloid		6.5	1	120–150 x 1–1.5	Fagus
14	Talæ.....	16	4255		rose or red	4–7	straight or slightly unequal		10–14	5		Celtis
15	cyathoidea...	4	3208	urceolate			ovoid					Amygdalus
16	leucoloma....	4	3209	cupulate	white		subglobular, ovoid					Ulmus, Lentiscus, Alaternus, Arbutus, etc.
17				disk	hyaline to rose	1.2–3	slightly crescent	acute	6.5–8	2.5–3.5	50 x 1	Fragaria

dent that this fungus does not attack sound berries but is secondary in its nature following one or another of the fungi mentioned above or gaining entrance through some mechanical wound.

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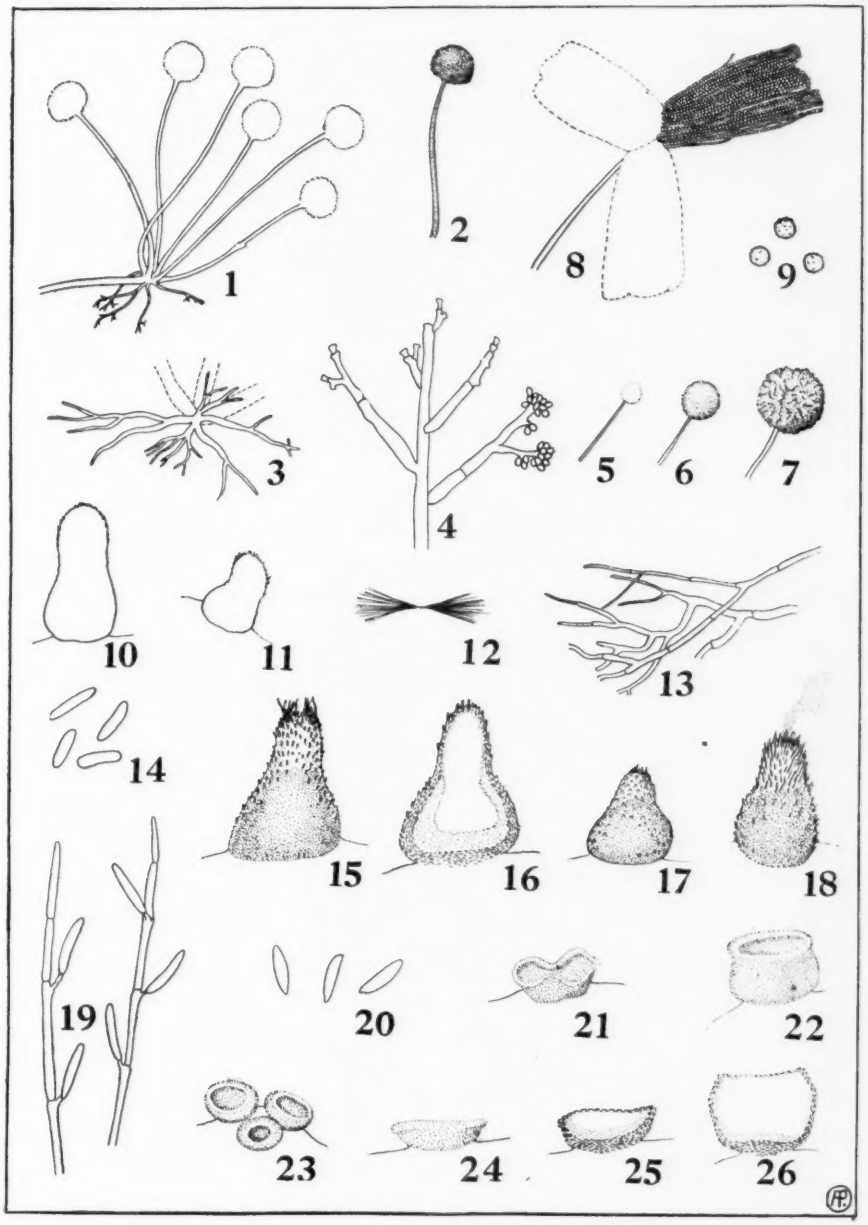
URBANA, ILLINOIS

EXPLANATION OF FIGURES

FIG. 1. Rhizopus nigricans showing sporangiophores and rhizoids.
FIG. 2. Rhizopus nigricans showing a single mature sporangium.
FIG. 3. Rhizopus nigricans showing rhizoids.
FIG. 4. Botrytis cinerea showing conidiophores and conidia.
FIGS. 5, 6, 7, and 8. Aspergillus showing stages in the development of a conidial head.
FIG. 9. Aspergillus showing spores.
FIGS. 10 and 11. Sphæronæmella Fragariæ. Outline drawings of perithecia.
FIG. 12. Sphæronæmella Fragariæ showing form of crystals found in pure cultures on agar.
FIG. 13. Sphæronæmella Fragariæ showing mycelium.
FIG. 14. Sphæronæmella Fragariæ showing conidia.
FIG. 15. Sphæronæmella Fragariæ showing perithecium.
FIG. 16. Sphæronæmella Fragariæ showing a section through a perithecium.
FIGS. 17 and 18. Sphæronæmella Fragariæ showing perithecia.
FIG. 19. Patellina Fragariæ showing conidiophores.
FIG. 20. Patellina Fragariæ showing conidia.
FIGS. 21, 22, 23 and 24. Patellina Fragariæ showing sporodochia.
FIGS. 25 and 26. Patellina Fragariæ showing section through sporodochia.



STEVENS AND PETERSON: STRAWBERRY FUNGI

COTTONY ROT OF LEMONS IN CALIFORNIA[1]

CLAYTON O. SMITH

WITH FIVE FIGURES IN THE TEXT

The decay of lemons, commonly known as cottony rot or white mold, may be found frequently in the lemon packing houses of California during the season from January to May. The loss here in fruit during the time of curing is often considerable.

The fungus causing the trouble is a species of Sclerotinia, and its occurrence on lemons has been discussed[2] in California Experiment Station bulletins and local horticultural papers. From spore measurements and other morphological characters the fungus has always been referred to the species, *Sclerotinia libertiana* Fuckel. To determine this point more fully, cultures supposed to be of this species were secured from different sections of the United States through the courtesy of several of the State Experiment Stations. Cultures were also secured from different localities in California where this or a very similar fungus was found attacking different plants. Results of inoculations of these strains on various hosts are summarized under artificial inoculations, table 1, and seem to show that the cottony rot fungus is identical with *Sclerotinia libertiana*.

Among species of Citrus, the fungus is found to attack the fruit of the lemon in the packing house, the twigs of oranges and lemons in the orchard, and rarely the blossoms of lemons. The chief loss is in the packing house where the fruit remains from one to two months before being shipped. The tents or rooms where the fruit is stored during the curing process are kept in a somewhat humid condition to prevent wilting of fruit. This condition is favorable also for the spread of the fungus. The spores from which the initial infection takes place are brought from the orchard into the packing house on the fruit, and are not all killed by the present methods of disinfecting the fruit as it passes through the lemon washer. The spores are given off from the apothecial stage of the fungus which occurs in the orchard under the vetch and other cover crops. From the initial infection a large amount of fruit may be infected by contact. This usually com-

[1] Paper No. 26, Citrus Experiment Station, College of Agriculture, University of California, Riverside, California.

[2] California Agr. Exp. Sta. Bul. 218:1123. 1911; California Cultivator **35**:No. 9. 1910.

FIG. 1. Apothecia of Sclerotinia. Developed from sclerotia growing in a pure culture which was isolated from a diseased orange branch.

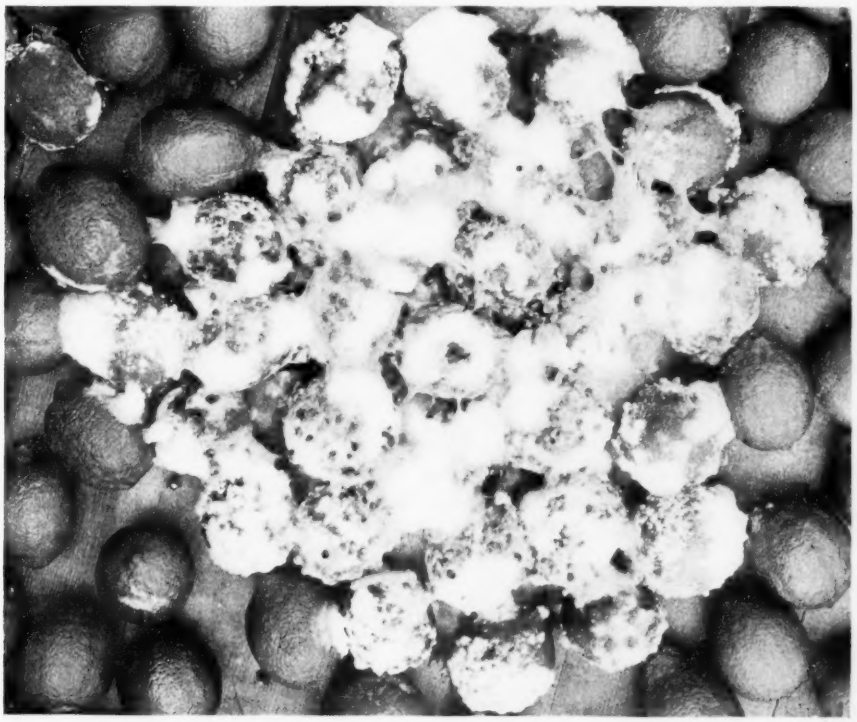


FIG. 2. Cottony rot as developed in packing house tray during storage.

prises most of the fruits in the half box where the rot is present (fig. 2). The disease sometimes spreads to other boxes of the stack, thus affecting a large amount of fruit.

The decay on the fruit is characterized by a white cottony-like mycelial growth that spreads over the surface of the fruit (fig. 2). The interior of the fruit after a time becomes diseased and the entire structure breaks down

FIG. 3. Natural infection of Sclerotinia in the fruiting wood of Eureka lemon.

into a more or less soft decay. After a time sclerotia are produced, but no conidial spores of this fungus have ever been found, either on the decaying fruit or in cultures.

The disease has been found in citrus seed-beds attacking both the sour- and sweet-orange stock. The shaded conditions here are favorable for the development of the fungus. The trees are grown close together and

usually small areas of them, comprising from six to a dozen or more trees, may be affected. The disease, however, is not regarded as a serious seed-bed trouble.

Nursery and orchard trees occasionally may be attacked. Small trees that have received winter protection with cornstalks are especially sus-

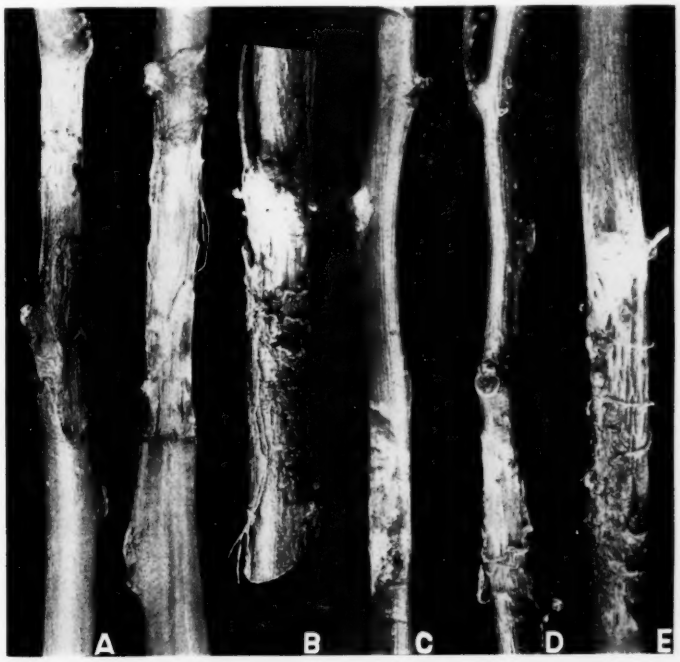


FIG. 4. Artificial infection on citrus twigs from inoculation with cultures of Sclerotinia. *A*, Orange twigs artificially infected with a pure culture of the avocado stain of Sclerotinia. *B*, Infection on lemon secured with a culture of Sclerotinia isolated from Eureka lemon twig. *C*, Infection secured with a culture of Sclerotinia, isolated from alfalfa stem, inoculated on lemon stem at leaf scar, the leaf being plucked immediately preceding inoculation. No other injury was made. Inoculation protected with waxed paper. *D*, Inoculation at leaf scar of lemon with a culture of Sclerotinia isolated from celery. *E*, Infection on lemon secured with a culture of Sclerotinia grown from sclerotia on soil under a vetch cover crop.

ceptible. On the larger trees the smaller twigs or more rarely larger water sprouts may be killed. The orchards affected are more frequently found in localities where and in seasons when the temperature has caused injury from frost.

The affected twigs show dead, dried, rolled-up leaves that remain attached for some months. The affected bark becomes a cinerous color and

at length fibrous. Gumming takes place especially near the margin of the infection and with the appearance of gum, further growth of the mycelium in the tissue is usually checked. The infections may extend one or two inches along the twig, gradually surrounding and killing it. While the fungus usually completely girdles the twig, it sometimes happens that the weather or other conditions become unfavorable and the fungus dies out without completely killing the twig. The disease on citrus twigs is rather of scientific interest than of economic importance, as the affected twigs are readily cut out at pruning time.

Under favorable conditions, the blossoms may be attacked and thence the fungus spreads into the fruiting twigs. The fungus probably starts in the decadent petals which may remain attached for some time. The blossoms of the lemons are produced in dense clusters, and a mass of these collapsed, partly dead petals give a favorable medium in which the fungus may become established as a saprophyte.

Sclerotinia libertiana is not restricted in California to Citrus as a host, but is found occasionally attacking other trees, plants, vegetables, green manure cover crops and weeds. It is at times parasitic on the blossoms of apricots,[3] attacking them while still enclosed by the calyx cup of the blossom. It was found, by H. S. Fawcett, of this Station, attacking the twigs of avocado, *Persea gratissima*, and is believed to have first gained its entrance through the collapsed petals in a manner similar to the attack of the lemon. The following are the hosts in California known to be affected by *Sclerotinia libertiana*, or a species closely resembling it morphologically and pathogenically: lemon fruits, twigs and blossoms, orange twigs, apricot blossoms, rarely avocado twigs, lettuce, tomato, celery, cucumber, eggplant, vetch, nettle (*Urtica urens*), and prickly lettuce (*Lactuca scariola*). These last two are common weeds in citrus orchards.

It is probable that the cottony rot has been gradually increasing with the growing of winter cover crops, especially of vetch. The dense growth of vetch affords a suitable place for the fungus to develop on the lower and more shaded parts of the plant. Here sclerotia are produced in abundance preparatory for the spore stage of the coming year. With the continued use of cover crops and mulches in the citrus groves, it is probable that the fungus will continue as an important factor in the decay of lemons.

The apothecial stage may be found from October to April under the cover crop or volunteer growth in citrus orchards, more especially those of lemon orchards. The fruiting bodies seem to be more numerous in or on the sides of the irrigation furrows, although they may occur at any place on the ground in the orchard.

[3] California Agr. Exp. Sta. Bul. 218:1097. 1911.

Artificial inoculations made on lettuce plants, after heading, with cultures of Sclerotinia, isolated from lemon twigs and fruit, showed characteristic softening and rotting under moist chamber conditions, in three to seven days. Spores from apothecia found in the orchard and applied to lettuce heads with a camel's hair brush, failed to produce infection after two weeks' time under moist chamber conditions, while inoculations with cultures made from such apothecia showed positive infection in five to seven days. The fungus, Sclerotinia, was again recovered from the above infections.

Artificial infection of lemons can be produced readily in a moist chamber with *Sclerotinia libertiana*: (1) by placing the mycelium or sclerotia into the tissue through a puncture or injury; (2) by placing mycelium on the uninjured surface of the fruit; (3) by placing a piece of an apothecium in the tissue through a puncture or injury; (4) by atomizing spores on the surface, in which case infection occurs only at the stem- and blossom-ends and at points in contact with moist chamber; (5) by inoculating the stem- and blossom-ends with mycelium of the fungus. In this case, infection develops within two weeks' time.

Inoculations on lemon fruits have been made repeatedly in moist chambers with the mycelium from pure cultures of *Sclerotinia libertiana* secured from several different sources. These are summarized in table 1. Orange fruits appear also to be equally susceptible, but have not been so thoroughly tested.

Inoculations with spores of the cottony rot fungus have been tested in different ways. Experiments in atomizing lemon fruits in a moist chamber, usually result only in the production of infections at the stem- and blossom-end. The germ tubes seem to be unable to penetrate the uninjured tissue. This fact is further substantiated by placing apothecia, spore-bearing surface down, in drops of sterilized water, or in drops of dilute prune juice on the surface of fruits. No infection takes place on the uninjured surface of the rind. An apparent exception took place in one experiment in atomizing fruit picked after several days of rain. This fruit was first sterilized with 4 per cent formalin which was rinsed off. The atomized fruit was kept in a moist chamber out-of-doors during the time of the experiment where the temperature was somewhat cooler than in the laboratory. In five days the five lemons were found to be infected at points where they were touching each other and at the stem- and blossom-ends. The probable explanation of this infection is believed to be the more susceptible condition of the fruit following cool, rainy weather.

Lemons have been inoculated with the spore dust from apothecia growing in a closed vessel. It is a well established observation that apothecia growing in a closed vessel will eject their spores as a dust-like puff. Lemons

were first moistened with water and then infected by allowing this dust to come in contact with the fruit which was then placed in a moist chamber and atomized with sterile water. Infection took place at the stem-end of fruits.

TABLE I.

Summary showing the results on various hosts of artificial inoculations made with the mycelium of various strains of Sclerotinia for the most part supposed to be Sclerotinia libertiana

SOURCE OF CULTURE[1]	LEMON FRUIT	LEMON TWIGS	ORANGE TWIGS	AVOCADO TWIGS	ENGLISH WALNUT TWIGS	APRICOT TWIGS	PEACH TWIGS	PLUM TWIGS
Lettuce, California	+	+	+	+	+		−	−
Lettuce, North Carolina	+	+				−	−	−
Lettuce, Maine	+	+	+			−	−	−
Lettuce Wisconsin	+	+			+	−	−	−
Ginseng,[2] Cornell University	+	+	+	+			−	−
Snapdragon, Maine	+	+	+	+	+		−	−
Beans, Maine	+	+	+	+		−	−	−
Lemon twigs, California	+	+	+	+	+	−	−	−
Lemon fruits, California	+	+	+					
Alfalfa, Oregon	+	+	+					
Avocado, California	+	+	+	+	+			
Cucumber, Oregon	+	+	+	+	+			
Apothecia, lemon grove, California	+	+	+	+		−	−	

[1] The author wishes to acknowledge the courtesy of the Experiment Stations of the states indicated in sending him cultures of Sclerotinia.

[2] The Sclerotinia of ginseng has recently been proved to be identical with *Sclerotinia libertiana* Rosenbaum, J. Pathogenicity and identity of *Sclerotinia libertiana* and *Sclerotinia smilacina* on ginseng. Jour. Agr. Research **5**: 291. 1915.

Soaking lemons for 36 hours in water in which spores of the cottony rot fungus were placed, gave negative results. Puncture inoculation in the tissue of lemon fruits with small pieces of an apothecium almost without exception produced infection.

The artificial infections on the lemon fruits with the different strains of Sclerotinia as indicated in table 1, showed the same general characteristics with the exception of the one from alfalfa. The fruits when inoculated with the cottony fungus show at first a discoloration and a slight softening of the rind. The color changes from the usual lemon color to that of straw (D).[4] No aerial mycelial growth takes place until from one to two weeks. At length, however, a dense white cottony growth with sclerotia covers the infected lemons.

[4] Dauthenay, Henri. Repertoire de Coulours, p. 31, No. 3.

The Sclerotinia from alfalfa is commonly referred to as *S. trifoliorum*. The artificial inoculations with this fungus on both the lemon twigs and fruit were much slower in developing than with the other strains of Sclerotinia. In the inoculated lemons the decay not only starts more slowly, but also shows a different color development in the affected tissue before the growth of the aerial mycelium. This color instead of being straw color, as described above, is a chocolate color (D).

In table 1, positive results are shown for all the artificial inoculations on the twigs of lemon with the various strains of Sclerotinia tested. Similar positive results are shown for many of these strains on orange twigs. The others were not tested on orange twigs, but would doubtless have given positive results. No successful inoculations were made on apricot, olive, peach or plum twigs. Positive results were secured from inoculations made on the English walnut and avocado. In these inoculations the infected bark became dark-colored, and at length fibrous. In all the artificial inoculations of the twigs, the mycelium of the fungus was placed between the loosened bark and wood and the injury wrapped with paraffin paper.

Avocado twigs have been successfully infected artificially with cultures of *Sclerotinia libertiana*, but are much more resistant than those of Citrus. In many cases the infection developed slowly and the fungus was only able to penetrate a short distance into the healthy tissue. The infected avocado tissue is readily recognized by its darker color. In more succulent or less vigorous twigs certain of the stains showed greater virulence and completely girdled the twig in two weeks' time. These infections are accompanied by the deposit of a white powdery substance on the surface of the twig (fig. 5). This deposit seems frequently to follow any sort of injury.

The English walnut is strongly resistant but successful inoculations on the less vigorous twigs have been made with certain of the strains of Sclerotinia (see table 1). It is of interest to note that *Sclerotinia juglandis* (Preuss) is described[5] as rotting the cotyledons of walnuts. From our present understanding of the hosts that *Sclerotinia libertiana* can attack, it would not be surprising if these two fungi proved to be identical.

The control of this decay can probably be best accomplished by the use of disinfectants in the lemon wash water. Copper sulphate 0.02 per cent is very generally used at present in the control of the brown rot, *Pythiacystis citrophthora*. In general practice, however, several of the common decays, including that of the cottony rot, are not so well held in check by the methods now in practice. This is thought to be partly due to several faults in the present methods. (1) All the wash waters contain carbon-

[5] Rabenhorst Krypt. Fl. Deut. Oesterr. U. d. Schw. Ascomyceten **3**:810. 1896.

ates in solution which unite with the copper sulphate as a basic copper carbonate, thus lowering the germicidal strength of the solution. This can be overcome by partly neutralizing the alkalinity with an acid such as

FIG. 5. Artificial infection of avocado with a culture of Sclerotinia isolated from snapdragon.

sulphuric acid. (2) The other factor which lowers the strength of the copper sulphate solution is the addition of hydrant water to replace that removed by the lemons in washing. This not only dilutes the germicide, but also adds more alkali thus causing more copper carbonate to be formed. This last difficulty can be overcome by adding copper sulphate solution, properly made, to the washing tank, to replace the water removed. Investigations of more efficient disinfectants in lemon wash waters are being made in greater detail by E. E. Thomas, of this Station.

In some preliminary studies there were indications that the use of a 25 per cent solution of alcohol preceding the use of the copper sulphate disinfection would give greater efficiency. This was tested to a limited extent in a packing house. Little cottony rot, however, developed in the untreated fruit, so the results were not as conclusive as could have been desired. No cottony rot developed in the seventy-eight boxes treated with 25 per cent denatured alcohol and then washed in acidified copper sulfate solution. In the check on the experiment with seventy-eight boxes washed in untreated hydrant water, one box showed cottony rot. In the experiment where the water was two-thirds neutralized with sulphuric acid before the addition of the copper sulphate to make a 0.02 per cent solution, there was one box that showed cottony rot out of the seventy-eight boxes treated.

The results suggest that further experimentation may prove that alcohol has some beneficial results in separating the spores from each other so they may be more readily acted upon afterward by the germicide.

GENERAL CONCLUSIONS

Research upon this disease has established the following facts.

1. Repeated inoculations have proved that the cottony rot is caused by a species of Sclerotinia, probably *Sclerotinia libertiana*.

2. That this fungus not only attacks the lemon fruit but also the twigs of mature and small orchard trees, nursery stock and sweet- and sour-orange seed-bed stock.

3. The hyphae of the vegetative stage of the fungus are able to enter and destroy a perfectly sound lemon at any point off contact, no abrasion being necessary.

4. Several strains of *Sclerotinia libertiana* from different localities of the United States, when inoculated in the fruit and twigs of lemons are pathogenic, showing infection similar in all characters to that of the lemon cottony rot fungus isolated from fruit and twigs of Citrus.

5. Attempts to inoculate the healthy uninjured skin of a lemon with spores applied with an atomizer over the entire fruit have failed, except

at the stem- and blossom-ends and rarely at points where two fruits are in contact.

6. The fungus has repeatedly been carried through its entire life cycle from ascospore to ascospore. No other spore stage has been observed.

7. Strains of Sclerotinia isolated from bean, cucumber, lettuce, vetch, wild lettuce (*Lactuca scariola*), twigs of Citrus, avocado, tomato, eggplant, appear to be identical with the organism causing decay of lemon fruits known as the cottony rot.

8. No more satisfactory method of control has been discovered than that now being used, a 0.02 per cent solution of copper sulphate in wash water, but certain improvements in method are suggested.

WHITTIER, CALIFORNIA

THE FORMATION OF PARENCHYMA WOOD FOLLOWING WINTER INJURY TO THE CAMBIUM

A. J. Mix

With Three Figures in the Text

The formation of a thin-walled parenchyma as an interruption in the normal wood ring has been mentioned by various European writers. T. Hartig[1] who calls tissue aggregations of this sort "zellgänge" speaks of their occurrence in the basal portion of the trunk of birch and hazel. De Bary[2] designates as "markflecke" areas of parenchyma tissue occurring in many woods both at the boundary and in the interior of the annual ring. He considers them hypertrophies of the medullary rays, but like Hartig, seems to believe that they occur normally in certain trees. Later authors recognized a pathologic condition. R. Hartig[3] and von Tubeuf[4] describe and figure parenchyma tissue as formed following lightning injury to the youngest wood elements of firs during the vegetative period Sorauer[5] mentions the phenomenon in several connections. It occurs in the case of edema of currant and gooseberry (pp. 335–336), where it is initiated by injury to the cambium; it may be observed in regenerative tissue formed after knife slits through the bark and cambium (pp. 766–768), after girdling (pp. 794–800), and after bending which has been severe enough to separate bark from wood (pp. 800–804). It is described and figured (pp. 614–621) as consequent to both natural and artificial frost injury to young oaks occurring during the early vegetative period; and the same author[6] states that he has observed parenchyma wood as the first tissue laid down in the spring, in the case of trees susceptible to injury from cold.

[1] Hartig, T. Vollständige naturgeschichte der forstlichen culturpflanzen Deutschlands. pp. 228, 326. 1851.

[2] De Bary, A. Vergleichende anatomie der vegetations-organe. pp. 507–508. 1877.

[3] Hartig, R. Untersuchugen über blitzschläge in waldbäumen. Forstl. Naturw. Zeitschr. **1897**: 108, 118.

[4] Tubeuf, K. von. Ueber sogennante blitzlöcker im walde. Naturw. Zeitschr. Land- u. Forstw. **4**: 344–351. 1906.

[5] Sorauer, P. Handbuch der pflanzenkrankheiten. **1**: 335–336, 612–621, 766–768, 794–800, 800–804. 1909.

[6] Sorauer, P. Experimentelle studien über die mechanischen wirkung des frostes bei obst-und waldbäumen. Landw. Jahrb. **35**: 469–525. 1906.

Sorauer explains this formation of parenchymatous tissue instead of normal thick-walled xylem elements as the result of lessened pressure on the cambium. This lessened pressure or loosened bark tension is brought about by the freezing process and one or both of two factors may be the immediate cause: clefts formed in the bark tissue, or a loss of bark elasticity consequent to too great tangential stretching. In the last case mentioned above the only factor which can be operative in lessening the bark pressure is a "stretching and loosening" of the cambial area brought about by freezing. It is stated as improbable that this tissue formation as the result of frost injury ever occurs in any but young and nearly herbaceous stems.

Kienitz[7] and Grossenbacher[8] observed parenchyma wood formation following injury by insect larvae mining in the cambium of various trees.

The writer has observed the formation of parenchyma wood in two cases, in which it followed what was, apparently, an injury to the cambium due to freezing while in the rest condition.

The first case was found in Clinton County, New York, in the spring of 1915. A number of 2- to 3-years-old apple trees in several orchards were observed on June 3 to be in an injured condition. The tops appeared dead, the branches and the upper trunk dry and shrivelled, but the bark, cambium, and sapwood appeared bright when cut across with a knife. The bark of the lower trunk, from the surface of the ground up for a distance of about one foot, was turgid and normal in color and general appearance. From various points in this apparently healthy area, green branches were emerging. On being cut into, the bark of this portion of the trunk appeared bright colored and normal, but a grayish brown discoloration was evident in the outer sapwood. This discoloration did not extend below the level of the surface of the ground. Closer examination of the discolored portion showed a zone of browned tissue in the outer sapwood, outside of which a zone of normal colorless wood was being laid down. Under the microscope the browned area was seen to consist of parenchyma wood. Internally, these trees showed some browning in the wood cylinder, especially in the medullary rays.

The above-described injury was attributed to winter-injury for the following reasons: (1) It was confined to one variety, the Rhode Island, a variety which according to the best local authority is not hardy in Clinton County nor in northern Vermont. One grower who had visited several orchards in northern New York and Vermont reported additional cases

[7] Kienitz, M. Die entstehung der "markflecke." Bot. Centbl. **4**: 21–27, 56–61. 1883.

[8] Grossenbacher, J. G. Medullary spots: A contribution to the life history of some cambium miners. New York Agr. Exp. Sta. Tech. Bul. **15**: 49–65. 1910.

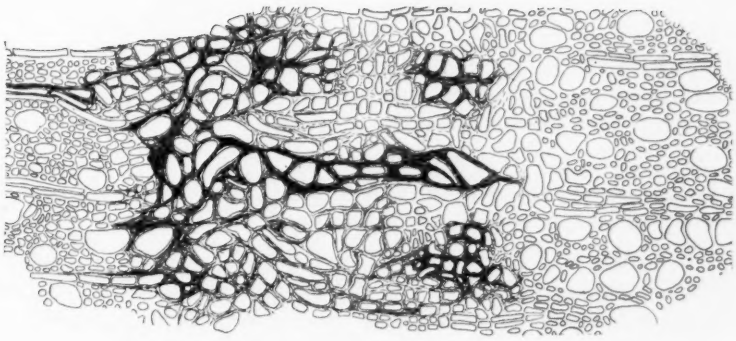


FIG. 1. Longitudinal section of injured zone in young Rhode Island tree, showing parenchyma wood between two layers of normal wood. The intercellular substance is represented by black shading. Outlined with a camera lucida. × 50.

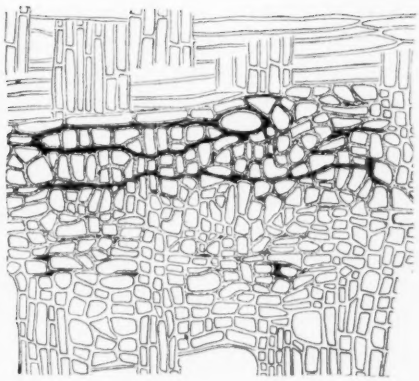


FIG. 2. Cross section of the same tissue shown in figure 1. Outlined with a camera lucida. × 50.

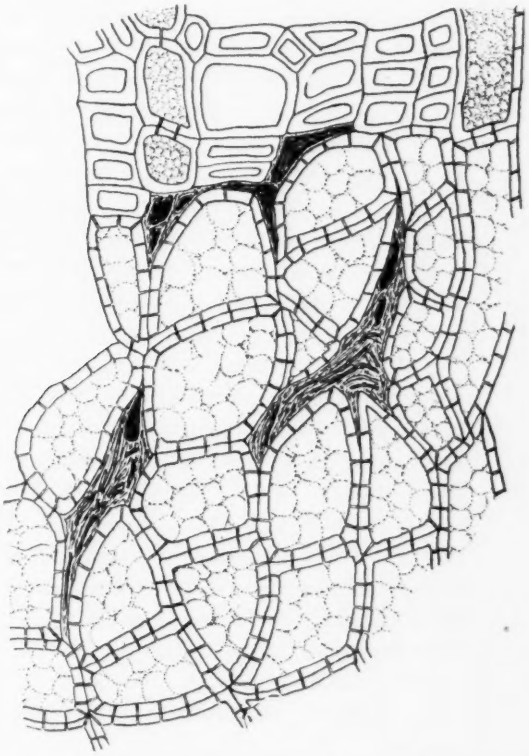


FIG. 3. Cross section through parenchyma wood zone, enlarged, showing origin of yellow substance from injured collapsed cambium cells. Note the remnants of cell membranes. Outlined with a camera lucida. × 350.

of the injury, all to the Rhode Island variety, and stated as his experience that it was not uncommon following severe winters. (2) The largest number of injured trees was found in an orchard, in which the trunks had been surrounded by tar-paper protectors during the winter, a practise which is considered by some orchardists to be conducive to winter injury.

The trees which were allowed to remain during the summer formed a new top from the new branches mentioned above. Internally, the trunks presented the appearance known as black heart, a fairly common type of winter injury in northern localities, in which a sound wood-ring surrounds a cylinder of dead, brown and brittle tissue.

The second case of parenchyma wood formation was even more plainly consequent to winter injury. During the winter of 1914–1915, in the course of some studies on winter sun-scald, a number of young trees were watched carefully for the occurrence of natural injury to the cambium. These trees stood in the University orchard at Ithaca, N. Y., were from six to eight years old and of the Northern Spy and Gano varieties. In the latter part of February several of the trees showed injury to the cambium and bark on the southwest side of the trunk.

In artificial freezing experiments (to be reported elsewhere) it was found that the portion of the cambial area nearest to the xylem, in other words the youngest xylem elements, was the area first susceptible to injury. More severe injury involved more of the cambial area up to its complete browning. Similarly, this natural injury varied in different cases from about 10 to 50 per cent of the cambial area, the injury always being on the side next the xylem. The injury was evidenced by a browning of the cell contents, the cell walls remaining colorless. There was no injury to the xylem itself, but there were a considerable number of cells in the cortex showing browned cell contents. There were no clefts in the bark due to separation of the tissues such as Sorauer describes for spring frost injury.

On October 30, 1915, these trees were again examined. The injury could only be detected by removing a cutting extending into last year's wood. It appeared as a brown line between the annual rings of 1914 and 1915. Microscopically, cross and longitudinal sections through this brown line showed that the first wood formed last spring was a comparatively narrow zone of parenchyma wood, that normal xylem was soon laid down outside of this zone, and the remainder of the wood-ring was normal.

The tissue described by Sorauer as "parenchymholz" which is here translated as parenchyma wood, is a tissue in which the normal xylem elements—wood fibers and vessels, are not recognizable. In their place has been formed an aggregation of irregular but nearly isodiametric cells,

with comparatively thin, pitted[9] walls and large lumina. The cells are, aside from their form, apparently normal; there is no discoloration in cell walls or contents; they are especially rich in starch. The medullary rays can be traced into this parenchyma zone and are seen to become enlarged and spread out tangentially (figs. 1 and 2).

At various places throughout this tissue there occur intercellular areas occupied by a yellowish brown amorphous substance. At first glance this appears like a browning in the cell walls, and at places the walls seem to be swollen as well as browned, but more careful examination shows that the cell walls are normal and that the yellowish brown substance lies pressed between them.

An attempt was made to determine the nature of this substance by microchemical tests but nothing definite was learned. It does not appear to be a gum like that occurring in gummosis of Prunus and Citrus, nor to be of the nature of wound gum. It does not swell nor dissolve in water, is not soluble in alcohol, nor in alcohol after treatment with potassium chlorate; colors brown with iodine, red-brown with chlor-iodide of zinc; stains readily and more deeply than the walls with various stains—safranin, Delafield's haematoxylin, fuchsin, Bismarck brown and methylene blue.

This yellowish brown substance indeed resembles very much the amorphous brown cell contents of cells injured by freezing, and it is believed to be merely the remains of the originally injured cells, collapsed and crowded together by the growth of later-formed cells. A glance at figure 3 will make this clear. Sorauer found fragments of the cell membranes in the yellow substance. The writer believes he has confirmed this.

It is to be pointed out that in these observed cases of parenchyma wood formation there were no bark clefts nor bark injury other than the killing of occasional cells; that any lessened tension which may have occurred could be due only to partial injury to the cambial area. Further, the tissue was formed in stems which were not "young and nearly herbaceous," and it is doubtful how much of a factor loosened bark tension could be in these cases. However, what stimulus induces the formation of this parenchyma tissue, is not apparent. It is seen to have resulted from an injury by freezing to the cambial area, in which the browning in no case involved more than the half of that area next to the xylem. Whether there was injury to cells which did not show browning could not be determined.

AGRICULTURAL EXPERIMENT STATION
GENEVA, NEW YORK

[9] Mention of the pitted condition of the walls is made by T. Hartig and De Bary, and not by the later writers, though it appears in their figures.

PHYTOPHTHORA INFESTANS ON TOMATOES[1]

F. D. Kern and C. R. Orton

With Two Figures in the Text

An unusual outbreak of *Phytophthora infestans* on tomatoes occurred in central Pennsylvania in 1915. It was especially notable in the experimental plats of the Pennsylvania State College. Inasmuch as it has not been reported previously on tomatoes from Pennsylvania it seems that a brief account of this outbreak may be interesting to pathologists.

That Phytophthora sometimes causes heavy loss to outdoor tomatoes has been recorded by Smith[2] in California and Reed[3] in Virginia, but a search through the American literature shows that the disease has been uncommon and not severe on tomatoes except occasionally in the above mentioned states.

In America the Phytophthora disease has been reported on tomatoes also from Maine and Connecticut by Thaxter[4] and from Massachusetts by Stone.[5] Clinton[6] however, says that the disease is evidently rare in Connecticut. Stone states that in 1905 the disease was prevalent in Massachusetts.

In Europe it is reported on the tomato by numerous authors. The disease has been reported from New Zealand by Anderson[7] and Cobb[8] states that it injures tomatoes in Australia. Apparently the Phytophthora occurs infrequently on tomatoes wherever this crop is grown near potatoes infected with the fungus.

[1] Contribution from the Department of Botany, Pennsylvania State College, No. 5.

[2] Smith, R. E. Tomato diseases in California. California Agr. Exp. Sta. Bul. 175: 9–15. 1906.

[3] Reed, H. S. Tomato blight and rot in Virginia. Virginia Agr. Exp. Sta. Bul. 192. 1911.

[4] Thaxter, Roland. Diseases of tomatoes. Ann. Rept. Conn. Agr. Exp. Sta. **1890**: 95. 1891.

[5] Stone, G. E. Downy mildew of tomato. Ann. Rept. Mass. Agr. Exp. Sta. **18**: 115. 1906.

[6] Clinton, G. P. Notes on parasitic fungi. Ann. Rept. Conn. Agr. Exp. Sta. **1903**: 365. 1903.

[7] Anderson, S. F. New Zealand Dept. Agr. Bul. 33: 18–19. 1913.

[8] Cobb, N. A. Agr. Gaz. N. S. W. **13**: 410–414. 1902.

That "late blight" is sometimes much more serious on tomatoes than on potatoes in the same locality is explained by Reed[9] on the ground that in such localities early varieties of potatoes are grown principally and that the period of greatest susceptibility for the potato is passed before weather conditions are favorable for its appearance.

The exact date of the first appearance of *Phytophthora infestans* at State College in 1915 is unknown but it was first recorded by the writers on potatoes August 23. It was probable at that time that it must have been evident at least a week previous to this date and perhaps sooner. It undoubtedly appeared on the tomatoes at the same time but was not actually observed until three or four days later. At that time it was wide spread in one of the plats where hybridizing experiments were being conducted on Yellow Pear and Enormous varieties. In this plat both

FIG. 1. Phytophthora infestans on tomato fruits. The grayish areas show well developed conidia.

varieties as well as the crosses were badly infected. In the larger plats, where one acre was divided into four plats, used for testing varieties of tomatoes for yield, and so forth, the disease was first noticed on plat 1 September 1. On September 4 it had progressed over plats 2 and 3 and on September 10 the entire field was badly infected and practically destroyed.

According to Professor Myers, who had charge of the tomato experiments, those varieties which were most susceptible to Septoria blight were least affected by Phytophthora blight. Unfortunately no records were kept on the resistance of varieties to Phytophthora but all of the 39 varieties grown in the acre plat were affected and the crop was almost a total loss.

[9] Reed, H. S. Does Phytophthora infestans cause tomato blight? Phytopath. **2**: 250–252. 1912.

The fungus appears to attack leaves, stems and fruit with about equal virulence. It was especially conspicuous on the fruits where the grayish patches of conidiophores stood out plainly against the darkened water-soaked areas (fig. 1). In connection with the appearance of the fungus on the stems it was especially noticeable that wilting did not occur in the distal portions until considerable time after a localized attack. The tissues might be collapsed entirely for a region of two or three inches on a stem (fig. 2), and yet the leaves on the portion above might show no indication of the presence of a disease for two or three days.

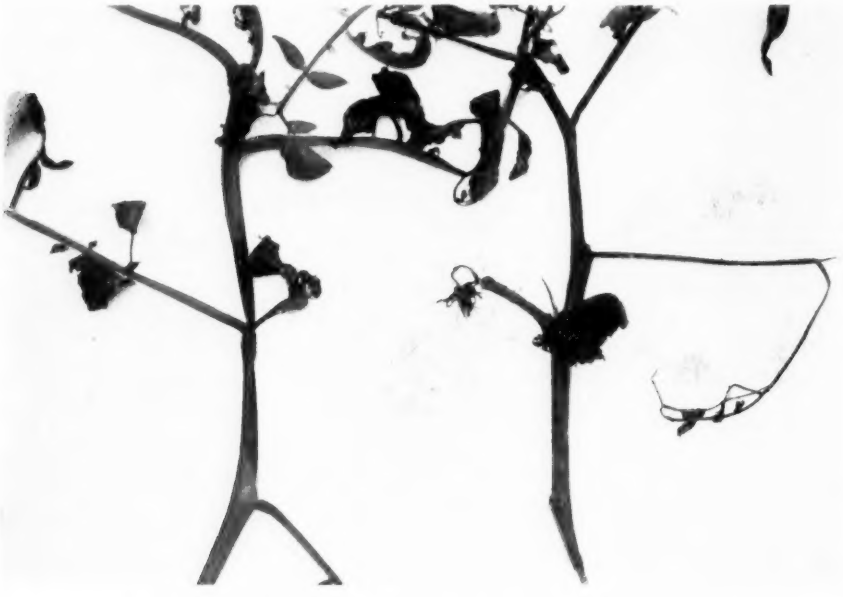


FIG. 2. Phytophthora infestans on the stems of tomato. On the left the stem tissues have collapsed but the leaflets above have not yet wilted.

A comparison of the yield this year with any normal year might be expected to show the extent of the loss due to the fungus. Such a comparison, however, would not be fair for owing to weather conditions and the unusual growth of the plants the yield would have been much decreased in 1915 without any blight whatever. The cool moist weather favored the production of heavy foliage and interfered with pollination to some extent so that the setting of the fruit was far less than in the previous season. What the blight did do was to affect so much of the fruit which did set that there was obtained from the Experiment Station grounds practically nothing of marketable value.

The possible connection between the weather conditions and an outbreak of a disease such as just described makes an interesting subject for consideration. This phase has been made the subject of special investigation by one[10] of the writers and it is not intended to discuss the matter here. It may be pointed out that the two features in which the weather varied in our region during the growing season of 1915 were the unusual low temperature and the excessive rainfall.

PENNSYLVANIA STATE COLLEGE
STATE COLLEGE, PENNSYLVANIA

[10] Orton, C. R. Meteorology and late blight of potatoes. (Abstract) Phytopath. **6**: 107. 1916.

OBSERVATIONS ON FIRE BLIGHT IN THE YAKIMA VALLEY, WASHINGTON[1]

J. W. Hotson

With Plates VII and VIII

During the spring and summer of 1915 several very peculiar conditions were observed in the study of fire blight in the Yakima Valley, Washington. Some of these were so radically different from what has been generally accepted regarding the way the blight organism works that careful observations and cultures were made in order to obtain as much light as possible on the situation. Fire blight on the fruit of Royal Ann cherries has already been reported.[2]

FIRE BLIGHT ON PEAR LEAVES[3]

An interesting case of leaf infection has been repeatedly observed on different varieties of pears, especially the Bartlett. This was particularly evident after a rain of which there were two unusually heavy ones during the early summer. This condition on leaves was first observed towards the end of June but it undoubtedly existed earlier in the spring than that. The infected leaves turn brown in sections, the brown areas always including a portion of the margin of the leaf. In some cases only a small portion of the leaf, extending in from the margin a quarter or half an inch, is affected while in others the affected area extends to the midrib, and in still others spread nearly or completely over the whole leaf. A few of these leaves are illustrated in plate VII, figure 1. In only a small number of instances were the leaves completely discolored or any evidence shown that the infection ran back through the petiole into the branch.

At first this condition was considered a sun-scald, but occasionally leaves were brought to the laboratory with exudate on them, particularly, as has been said, after a rain. On one occasion, July 7, leaves showing exudate were examined in conjunction with F. D. Heald, pathologist of the

[1] Abstracted in Phytopath. **6**: 115–116. 1916.

[2] Hotson, J. W. Fire blight on cherries. Phytopath. **5**: 312–316. 1916.

[3] Since submitting this article for publication the writer's attention has been called to a recent bulletin by F. D. Heald entitled Preliminary note on leaf invasions by Bacillus amylovorus. Washington Agr. Exp. Sta. Bul. 125.

State College of Washington. A microscopic examination of this exudate showed that there was a large number of bacteria present, which suggested fire blight. To determine definitely if these discolored areas were the result of *Bacillus amylovorus*, tube cultures were made from the exudate and also from infected pieces of leaves. The bacteria that appeared in these cultures were then transferred to green pears which had previously been sterilized and treated in a manner similar to that previously described.[2] As a result of these experiments, over ninety per cent of the cultures taken from the exudate readily produced the characteristic fire blight colonies on sterilized pears. Of the cultures taken from leaves that showed no exudate a much smaller proportion of infections was obtained. A large number of gross cultures was also made of discolored leaves showing no exudate. In these cases a portion of the leaf was transferred directly to the sterilized pears in moist chambers. Of these less than ten per cent indicated the presence of living organisms.

The organisms in the leaves apparently soon die, probably as a result of the action of the direct sunlight combined with the heat, which often reached 45 to 50°C. on a hot day. This would account for the low percentage of living organisms found on these leaves and also for so few instances of twig infection as a result of the organisms working back through the petiole.

As far as the writer is aware this represents an entirely new mode of attack by the fire blight organism. It would appear that the bacteria gain entrance either at the margin or through punctures in the leaves near it. The fact that invariably a portion of the margin is included in the discolored area would tend to point to it as the place of entrance. This theory is emphasized by the fact that not infrequently the margin appeared to have been injured, often having a small crack or split through which the organism may have entered. There were, however, not a few instances in which no evidence of an abrasion or puncture could be detected on the leaf when carefully examined with a hand lens.

FIRE BLIGHT IN THE SAPWOOD

Another interesting condition has been observed in connection with fire blight in the Yakima Valley, on the Comice pears and less frequently on Winter Nelis and Bartlett pears. On several occasions, and from widely different sources, the writer's attention has been called to a condition occurring on limbs and twigs infected with fire blight where the sapwood and sometimes the pith showed a decided reddish color similar to the red streak that is characteristic of fire blight. A photograph of a number of branches of the Comice pear showing the coloration in the sapwood is reproduced

in plate VII, figure 2. Many of these branches were three-quarters of an inch in diameter and apparently not any more severely affected than hundreds of others that did not show this peculiarity. In some cases this color was manifest a foot or eighteen inches beyond where the bark showed discoloration. The grower, in whose orchard this condition was most prevalent, maintained that in order to be effective the cuttings for fire blight must be made beyond this red streak. He attributed practically all his reinfections at the wounds to a failure to get beyond this condition. In consequence of this he adopted the plan of examining each cut, and if the streak appeared, to cut farther back. He considered that only by so doing was he safe from further infection.

An effort was made to determine whether this peculiar condition was caused by the blight organism or merely associated with it. Many examinations of twigs and branches were made, the red streak always being found on limbs that were or had been blighted and never on perfectly sound, normal branches. From this fact it was concluded that this condition was due directly or indirectly to fire blight. Gross cultures and also tube cultures were made of the red sapwood with varying results. In only a few instances did gross cultures on pears, such as has already been referred to, produce the characteristic fire blight reaction. Better results were obtained when the twigs were split, a small portion of the colored sapwood detached with a sterile knife and transferred to tubes of glycerine or bouillon agar. When bacteria appeared in quantity, a portion of agar with as many of the bacteria as possible was gouged out and transferred to the sterile pears. Under such conditions some undoubted blight organisms were obtained, but not as readily or abundantly as from similar cultures taken from the bark. In the bark, the organisms are regularly found beyond the characteristic red streak, while in the sapwood no organisms could be obtained towards the outer limits of the colored area.

It would appear from these observations and experiments that under certain conditions of terminal or fruit-spur infections, the bacteria may invade not only the bark but the young sapwood and even the pith. Miss Bachmann[4] has already shown that these bacteria may readily enter the xylem tubes which, "in some places in a shoot, are so packed with the organisms that the transmission of sap in such a region seems quite impossible." When the organisms attack the young shoots, destroying the tissues, the bacteria have practically free access to all the cells. Among others they succeed in entering the xylem tubes and even the pith. As the cells at the end of a recently infected twig gradually become killed,

[4] Bachmann, Freda M. The migration of Bacillus amylovorus in the host tissue. Phytopath. **3**: 3-14. 1913.

the so-called "negative pressure" may be set up, aiding the organisms to migrate backward from the tip in the tracheae. The color, or that which produces it, is carried beyond the organisms.

It has been observed in connection with some other experiments that, when tips of branches were cut under water and immediately placed in a bottle containing a certain solution, a four-ounce bottle was emptied within a few hours. It seemed desirable to know through what tissue this liquid passed. For this reason bottles of eosin were used instead of the colorless solution and it was found that to a certain distance the coloring matter was equally distributed through the sapwood, wood and pith but that it travelled farther in the sapwood than in the pith, while there was practically no trace of it in the bast tissues of the bark. It would appear from this that liquids will pass readily in the sapwood from the tip of a branch backward, at least under conditions found in the Yakima Valley where the weather is extremely dry and warm during the summer.[5]

The red streak was often found six or eight feet from the tip of the branch, but no organisms were obtained in this region. Nearer the tip, however, frequently extending two feet from it, the bacteria were plentiful. Sometimes in older branches of a preceding year's growth, that were over an inch in diameter, this streak could be detected readily. In such cases, however, as is shown in figure 3, a and b, plate VIII, the infection could be traced to a small lateral branch, the organisms gaining entrance to the xylem tubes near the tip and then working their way back into the larger limb, the coloration extending beyond the region of the organisms. This condition was frequently found in fruit-spurs running back not only in the sapwood but also in the pith. Sometimes the red pith would extend six inches or a foot from the tip but in no case, either with the red pith or red sapwood, could living organisms be obtained towards the limit of coloration.

FIRE BLIGHT IN THE YAKIMINE

Fire blight on the Yakimine, a cross between a prune and a peach, has been found frequently. An example of terminal infection of a Yakimine appears in plate VIII, figure 4.

FRUIT INFECTION

There was observed during this season an abnormal amount of fruit infection on both apples and pears. In many instances these were out of

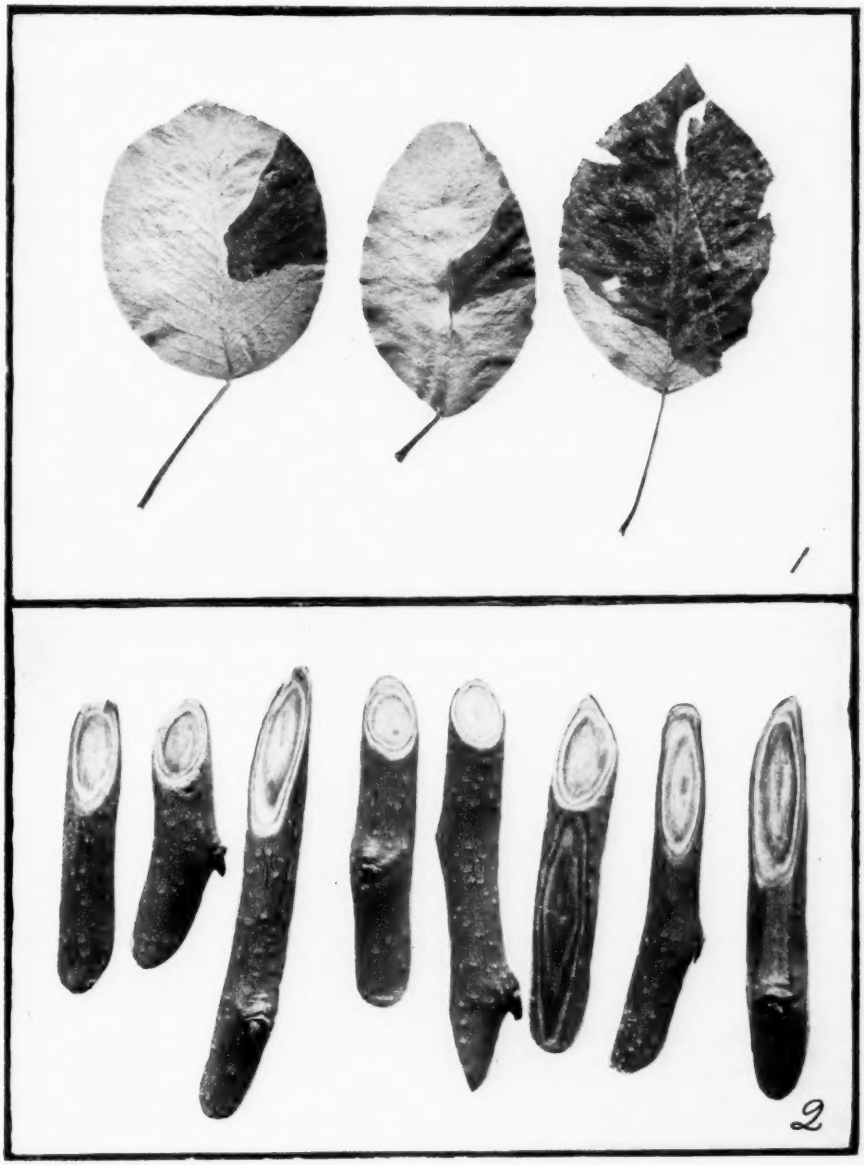
[5] Similar experiments with eosin conducted at Seattle, Washington, during November and December, when it was raining nearly every day, gave practically the same results.

all proportion to the number on the twigs and branches of the trees. An excessive number of insect punctures on the fruit may have been the cause but no definite evidence could be obtained on this point. In some cases this abnormal condition was traced directly to the manner of thinning the fruit. It was found that in a certain orchard a large percentage of the fruit infections occurred at the fresh wounds made by pulling off the apples when thinning. In the same orchard practically all stages of infection were observed. In some cases it could be detected only a few centimeters from the wound; in others it extended down into the fruit spurs, while in still others it had extended not only into the fruit spur but out into the fruit, as is shown in figure 5, plate VIII. At the point (*a*) in this figure are beads of exudate.

On August 11, 1914, a severe hailstorm swept over the Fairview district, a short distance from North Yakima, almost defoliating many of the fruit trees. About ten days after the hailstorm numerous new fire blight infections were observed on pear trees in this vicinity and a week later had reached the proportions of a serious epidemic, threatening the whole district. On examination it was found that the hail had made deep wounds in the bark of the young twigs, the organisms evidently gaining entrance at these injuries. More conspicuous than twig infections, were those on the fruit. On many trees two-thirds of the pears were injured by the hail and of these fully half became infected with fire blight. On large trees ten or fifteen years old where the growth during the summer had been slow but substantial, few twig infections occurred but 50 to 60 per cent of the injured fruit soon began to show evidence of disease. In many instances an abundance of infected fruit was found on trees that had no evidence of being previously infected. The rapid spread of the disease to uninfected trees was probably due to various kinds of insects, especially ants attracted to the fruit by the exuding juice. A greater number of infections occurred on the fruit as it was more susceptible to the disease than the twigs. To guard against a more serious epidemic the injured fruit was immediately picked and destroyed. With this precaution the disease was no more serious in this region the following spring than in other districts where there was no hail.

The writer is indebted to Mr. Henry Schmitz and Mr. C. E. York for taking the photographs.

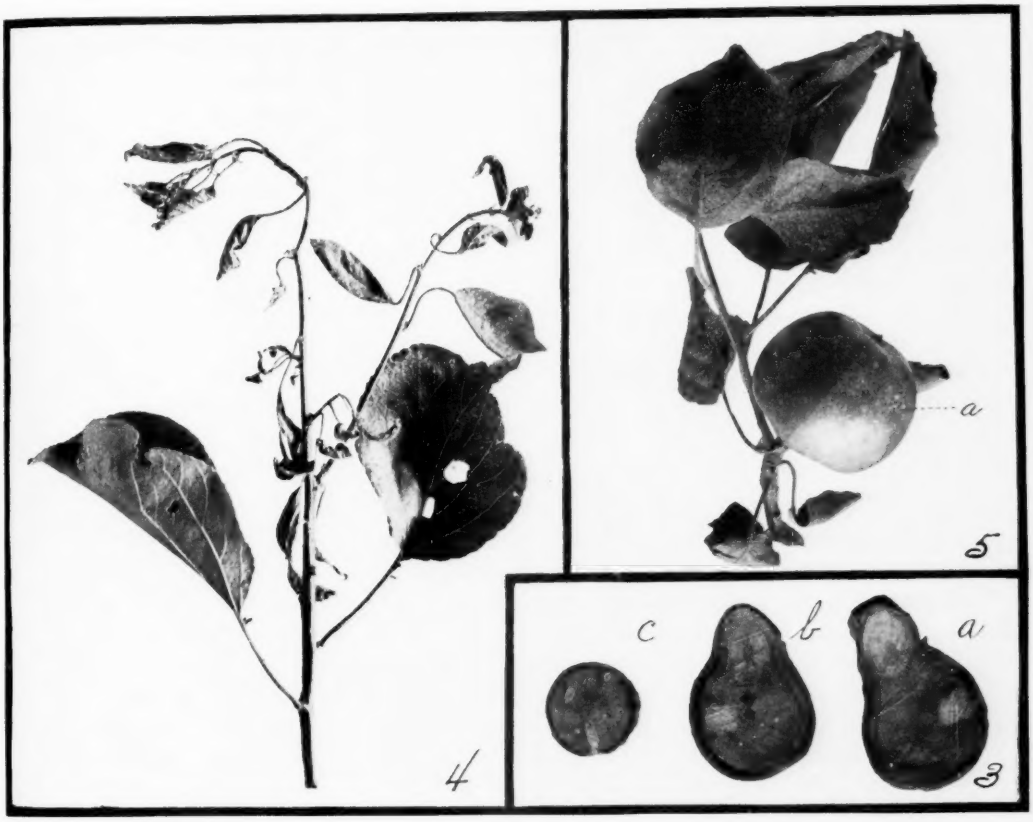
UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON



HOTSON: FIRE BLIGHT

FIG. 1. Fire blight on the leaves of Bartlett pears.

FIG. 2. A series of cuttings from branches of the Comice pear showing the coloration in the sapwood.



HOTSON: FIRE BLIGHT

FIG. 3. Cross sections of a two-years-old branch of a Bartlett pear showing the presence of the red streak which had been introduced by infected lateral branch as shown in *a* and *b*. In *c* the bark has been removed.

FIG. 4. Fire blight on the Yakimine.

FIG. 5. Fruit infection as a result of thinning apples.

REVIEWS

Gribnye Parasity Vysshikh Rastenii Kharkovsk. i Smezhnykh Gubern. A. A. Potebnia. Kharkov Obl. Selskokh. Opyt. Sta., No. 1, str. 1–120, ris. 1–19. 1915. (Fungous Parasites of the Higher Plants in Kharkov and Adjacent Provinces. A. A. Potebnia. Kharkov Prov. Agr. Exp. Sta., No. 1, pp. 1–120, figs. 1–19. Kharkov, 1915.)

Upon the reorganization of the Kharkov Provincial Agricultural Experiment Station in 1913, with jurisdiction over practically all of four adjoining provinces, and the establishment of a well equipped department of plant pathology, A. A. Potebnia, pathologist in charge, made a thorough plant disease survey of this region. He now proposes a series of publications, based on his actual observations and studies as well as on the previous literature which, when completed, will cover every group of the fungous parasites and diseases with illustrations of the most important ones. The above book is the first number of this series and deals with the three lower classes of organisms, namely, Bacteria, Amoebae, and Phycomycetae. Attention is given to those forms which are actually found within the territory of the Kharkov Station, as well as to those the eventual discovery of which might be expected.

It is of interest to note that several important parasites, occurring either in Europe or in America or in both these countries, as yet have not been found in Russia or, at least, no typical outbreak has taken place to warrant a definite conclusion. They are as follows: *Bacillus phytophthorus*, *Bacillus amyloverus*, *Spongospora subterranea* and *Synchytrium* (*Chrysophlyctis*) *endobioticum*. On the other hand, three new plants are described which as yet have not been reported in this country. As they may prove to be of considerable pathological significance and as no Latin diagnosis accompanies their Russian description, mention of a few more important details regarding their characters will not be superfluous.

One is a bacterial organism, named *Bacillus petroselini* n. sp., and is accounted the cause of a leaf spot of *Petroselinum sativum*. The spots are small, 2 to 3 mm. in diameter, limited by the veins of the leaves, yellowish with a brown border. The parasite gains entrance through the stomata and disorganizes the tissues, forming cavities filled with the bacteria. In the resting state, in the host tissue, the bacillus is small, almost coccoid, 0.8 by 0.5 μ, while in the motile state the size is up to 5 by 1 μ. Occasionally, resting rods are found as large as 8 to 9 by 1.5 μ. It forms large

zoogloeae, reaching 100 μ or more in diameter. The colonies on beef agar and gelatin are white at first, then turn okra-yellow. The gelatin is not liquefied. A long period of drying does not kill this bacillus and typical pure cultures were obtained from dry, two-years-old, herbarium material. No mention is made of inoculation experiments. The bacterium is said to be of the same type as *Bacillus burgeri*[1] and *Phytobacter lycopersicum*. It is to be regretted that the description is not completely worked out according to the chart of the American Bacteriologists, nor is the group number given; therefore, it would be difficult to identify this organism in this country should a similar trouble be found here.

Two other plants belong to the group of Amoebina (Monadineae) and are named *Pollinopsis betae* nov. gen. et sp. and *Amoeba cucumeris* n. sp. The first form was found to be associated with a disease of beets caused by *Bacterium beticola* Erw. Sm. The author has no doubt that the same organism was observed by J. Brzezinski, of Cracow, and named by the latter *Myxomonas betae*. However, the life history of this amoeba was not correctly understood by Brzezinski and none of the six stages of development described by him actually exists. For this reason a new name is given. Potebnia succeeded in isolating *P. betae* and growing it in cultures. A study of its life history shows the presence of two stages, (a) amoeba and (b) cysts. The amoebae have an elongated shape, are from 15 to 25 μ (maximum 45 μ) in length, and move forward at one end, at which the ectoplasm sends awl-like pseudopodia in various directions. The middle and posterior portions of the body are filled with a granular, greenish endoplasm. The nucleus is found in the middle or nearer to the anterior end. The back portion contains a vacuole and during the motion of the amoeba is always accompanied by a dense cluster of bacteria, actively motile and apparently attracted by some secretion of the amoeba. As soon as the food is exhausted, the bacterial bundle disappears. The amoeba undergoes various changes in shape and appearance and finally turns into the resting stage or cyst, with a brown, double-walled, protective membrane at maturity. On germination the contents of the cysts emerge through an opening in the membrane and soon become young amoeba, without pseudopodia at first, but later on taking a typical appearance as described. The presence of the bacterium seems to be necessary for the growth of this organism. Whether a definite substratum, i.e., beet tissues, is also necessary for it is a question which is yet to be solved. The finding of this organism in connection with an apparently

[1] This name is given by A. A. Potebnia to the organism described by O. F. Burger in Florida and considered to be identical with one causing a similar trouble of cucumbers in Russia.

identical disease of beets in widely separated regions suggests that the association is not a casual one.

Amoeba cucumeris was isolated from sticky exudates which appear on cucumber fruits affected with *Bacillus burgeri*. Examination of herbarium specimens from Bubák and Kabát (Copenhagen), affected with a similar disease, revealed the presence of the cysts of the same organism. They are hyalin, oval, pear-shaped, or asymetrical, occasionally almost round, measuring 5 to 7 by 3 to 4 μ, surrounded by a thin membrane which is very difficult to stain when mature. The cyst germinates in broth or beef agar by bursting at one side and the contents flow out in the form of an amoeba. The latter are also hyalin, 5 to 20 μ in diameter, and begin to move immediately upon emerging. This organism is not thought to be pathogenic, but its constant association with certain bacteria, as is the case also with some other amoeboid organisms, raises an interesting question in regard to their rôle during the development of the disease and their relation to bacteria. There was no particular difficulty in obtaining cultures of *A. cucumeris* on ordinary beef agar, but its multiplication was observed only when bacteria were present. An interesting process of feeding upon these latter is described. Bacteria-free amoebae usually formed an aggregate plasmodium. The author made a series of experiments in order to determine the relation of this amoeba to various other bacteria, by inoculating with it pure cultures of eighteen different species of Bacillus, Sarcina and Vibrio. He found that all of them are fitted for the food of the amoeba. However, *B. burgeri*, a bacterium of the type *Semiclostridium commune*, *B. coli communis*, and *B. typhi abdominalis* were destroyed most rapidly and most completely.

In conclusion, two remarks may be added regarding the terminology accepted by Protebnia in his book. The transcription of the names of large groups with the commonly used suffix "mycetes" is the same as that introduced by Saccardo beginning with Volume XIV of "Sylloge," i.e., Schyzomycetæ, Myxomycetæ, Phycomycetæ, etc. (meaning *plantae*). In the specific names the suffix "cola," as a noun derived from the Latin word "colo," is preserved unchanged regardless of the generic designation; therefore, *Bacterium beticola*, etc. (the same as *agricola*). If the rules of etymology are to be observed, these two points seem to be well deserving of consideration.

MICHAEL SHAPOVALOV

Bitter pit investigation. The past history and present position of the bitter pit question. McAlpine, D. First progress report. 197 pp., 33 plates and frontispiece. 1911–12.

Bitter pit investigation. The cause of bitter pit: Its contributing factors together with an investigation of susceptibility and immunity in apple varieties. McAlpine, D. Second progress report. 224 pp., 60 plates and frontispiece. 1912–13.

Bitter pit investigation. The control of bitter pit in the growing fruit. McAlpine, D. Third progress report. 176 pp., 37 plates and frontispiece. 1913–14.

Bitter pit investigation. The experimental results in their relation to bitter pit and a general summary of the investigation. McAlpine, D. Fourth report. 178 pp., 40 plates and frontispiece. 1914–15.

The last of a series of four large volumes on the subject of bitter pit of pome fruits has recently been published by McAlpine. The series of publications furnishes by far the most elaborate treatment ever given this subject and is probably the most voluminous report that has ever been made upon any single plant disease. It gives a full review of the literature and is illustrated by nearly four hundred figures.

The description given of the disease in its typical form is similar to that found in earlier publications on the subject. The writer, however, includes what is known in the western United States as hollow apple as a form of bitter pit, calling it confluent pit or crinkle. Some of the figures would indicate that spots which in the United States have been called stigmonose, and others which have been attributed to extreme drought or to peculiar soil conditions, are also included under the term bitter pit. It is stated that the disease usually develops in storage or as the fruit is approaching maturity but often occurs when the apple is one-half or three-quarters grown. The wide latitude the author gives in time of development is probably made necessary by the great inclusiveness given the term.

As to the cause of the disease, McAlpine rejects White's theory that bitter pit is due to local poisoning by spray material, and supports his opinion by experiments showing that the disease is as common on unsprayed as on sprayed trees and by chemical analyses showing that arsenic is not present in bitter pit tissue. He also rejects Ewart's theory that bitter pit may be produced by poisons absorbed by the roots, pointing out that Ewart has not considered the effect that these poisons might have on the roots themselves, and giving experimental data to show that bitter pit did not develop on the fruit of detached branches when their stems were allowed to stand for more than two weeks in solutions of copper sulphate or mercuric chloride, nor did trees that were watered

with a copper sulphate solution show any increase in the disease. The latter experiment, however, was considered rather inconclusive. In his first report the theory of Pole Evans that the diseased condition is produced by the bursting of the cells from too great internal pressure is rejected because it seemed to offer no explanation for the fact that the disease develops only in certain parts of the apple and because a microscopical examination showed that the cell walls of the affected tissue were in reality not ruptured. In the fourth report he suggests the possibility that the rupture of the cells from turgor may in some cases be the cause of the disease.

McAlpine accepts the theory presented by Wortmann and later supported by Zschokke, that the death of the cells in the case of bitter pit is due to the concentration of the acid of the sap resulting from loss of water, but he does not accept the main proofs they offer in support of the theory. The author's whole discussion of the cause and nature of the disease, however, may be considered an elaboration of the above theory. He thinks the theory accounts for the development of the disease, both in storage and on the trees, and in the latter case for its development in wet as well as in dry weather. During dry weather or when dry and wet weather rapidly alternate, the lack of water in the cells is brought about by transpiration exceeding the water supply. When there is continued wet weather or when the fruit is unduly forced from any cause, the death of the cells by drouth results from the fact that the pulp tissue grows so rapidly that there is not time for the formation of the new vascular tips that are needed to supply them with water. In the first volume the writer seems to ignore the ability of water to pass readily from one pulp cell to another, but later he states that this transfer is not rapid enough to supply the needs of the pulp cells in the case of such rapid growth. No proof is given that new terminal vascular tissue is formed in the nearly mature apple when it is making a less rapid growth. In the first volume the writer lays great stress upon the smaller vascular bundles near the surface of the apple, and states that the failure of other workers to find a solution to the problem lies in the fact that they never suspected the existence of these. These vasculars were described and partially figured by Grew as early as 1682 and their existence is a matter of common knowledge among botanists. The excellent photographs and descriptions of the vascular tissue of the apple in the volumes under consideration do not need such extreme assumptions to establish their worth.

From weather records and orchard observations the author comes to the conclusion that the disease may be bad in either wet or dry seasons and that a sudden change in the water supply furnishes the most favorable condition for its development. Irrigation experiments were performed

without very definite results, but there was slightly less pit on the trees receiving two irrigations than on those receiving one.

Extensive fertilizer experiments were made in various sections of Australia. The results varied with the soil and the weather and no general conclusions could be drawn. The results as a whole, however, showed an increase rather than a decrease in the disease from the use of fertilizers. Green manuring seemed to decrease the disease.

Of all orchard operations pruning was found to have the most direct effect upon the development of bitter pit, excessively pruned trees developing the greatest amount of the disease. Cincturing of trees or limbs was found to reduce the disease.

A very full discussion is given of the relative susceptibility of varieties, and explanations are offered for the differences found. Chemical analyses of normal and diseased fruit are reported.

Storage experiments showed that uniform low temperatures (30°–32°F.) retarded the development of bitter pit, while high and fluctuating temperatures (35°–60°F.) were favorable to its development.

The illustrations are excellent and in addition to the full report on bitter pit many interesting horticultural notes are given.

CHARLES BROOKS

PHYTOPATHOLOGICAL NOTES

Pleosphaerulina on alfalfa. The note by Mr. Leo E. Melchers, of Manhattan, Kansas, on "A new alfalfa leaf spot in America" in Science n. s. 42, no. 1085: 536, October 15, 1915, leads the writer to contribute this note, which adds certain facts regarding the distribution, cultural habits, and taxonomy of this fungus.

While investigating certain diseases of alfalfa leaves at Madison, Wisconsin, the writer in July, 1914, first isolated Pleosphaerulina from alfalfa leaves. The cultures were obtained from small spots, which before that time were not distinguished from early stages of the spot caused by the fungus *Pseudopeziza Medicaginis.* The two spots were frequently intermixed on the same leaflets in varying proportions. The distinction is not a difficult one when the small, delimited, depressed, brown or gray center of the Pleosphaerulina spot is once noted. These small, uniform spots, 1 to 2 mm. in diameter, have often been found scattered abundantly over the leaves of young, vigorous plants when the large, dead areas bearing perithecia were difficult to find.

On March 3, 1915, alfalfa plants were received from Mr. H. B. Tisdale, Auburn, Alabama, bearing many of these minute spots all over the foliage. When the younger leaves were decolorized in acetic acid and alcohol and examined under the microscope, a large, dictyosporous spore was found in the center of almost every spot, and usually the penetrating germ tube could be observed. Further careful search of the material revealed a few perithecia on the stipules, producing spores similar to those found on the spots. Cultures from single spores from these perithecia and from platings from the small spots on the leaf were indistinguishable from each other, and likewise indistinguishable from the cultures from similar spots previously found on alfalfa at Madison, Wisconsin. Similar cultures have been obtained from ascospores from larger spots on leaves and from blackened stems of alfalfa plants sent by Mr. Eubanks Carsner from Norfolk, Virginia.

In addition to collections already mentioned, viz., from Alabama, Virginia, and Wisconsin, the fungus has been collected during the past summer by the writer from points in Iowa, Minnesota, and South Dakota, and by Mr. R. D. Rands in Indiana.

In pure culture, black, perithecial structures appear abundantly, but under ordinary conditions these fail to produce spores. After many experiments, it was found that in young cultures on oatmeal agar and

potato agar kept constantly at the temperatures 7.5°, 5°, and 1.5°C., spores matured somewhat sparingly in from 14 days at the higher temperature to 90 days at the lower temperature. This led to the discovery that in similar cultures kept out of doors in a shaded place spores matured abundantly, especially in the spring and fall.

A number of inoculations of normal alfalfa plants in the greenhouse have been made with these ascospores, but with no certainly positive results. However, from the evidence of leaf penetration by germ tubes, referred to above, and the appearance of the disease in the field, there seems no doubt that the fungus is under certain conditions a parasite. Further work is needed to determine the special conditions under which infection occurs.

The identity of the fungus with previously described species was not clear from the published descriptions. Hence it was arranged by Mr. Melchers and the writer to submit their collections to Dr. C. L. Shear for comparison with available exsiccati. This he has kindly done, and the following quotation from his letter, published with his consent, gives his findings.

"No. 383, Briosi and Cavara, Fun. Par. Exs. This specimen shows perithecia, asci, and ascospores, agreeing in every respect with Pollacci's illustration in his original publication of *Pleosphaerulina briosiana*. The ascospores measured 25 to 28 by 12 μ and eight to ten asci were found in some perithecia. Pollacci's original description gives 20 to 25 by 6 to 8 μ for spore measurements. This I fear is an error[1] as none of the European specimens we have examined show spores of these widths. The ratio between length and width in his measurements does not agree with that shown in his original figures of the spores. The ratio in his drawings is approximately that given by our measurements.

Another European specimen, 1290, D. Saccardo, Myc. Ital., shows asci and spores of the same size and appearance.

The specimen sent Mr. Melchers by Bubák from Moravia also agrees with the others just mentioned. There are occasionally found young or imperfectly developed spores 18 to 20 μ long. In the American specimens from Kansas and those from Wisconsin and Iowa we find quite constant and uniform measurements of ascospores ranging from 25 to 30 by 12 to 14 μ. In number of asci, in shape of asci, and in size and character of perithecia we find little or no difference between the American and European specimens. We are therefore of the opinion that they all belong to the same species, *Pleosphaerulina briosiana* Poll."

FRED REUEL JONES

[1] Bubák likewise suspected that this measurement was given incorrectly, and upon obtaining original material from Pollacci, found this to be the case. Wiener Landw. Zeit. **59**: 909. November 20, 1909.

Dissemination of bur clover leaf spot. Bur clover (*Medicago arabica* and *Medicago hispida*) is more or less severely attacked in portions of Alabama by one of the leaf spot fungi, *Cercospora Medicaginis* E. & E. The disease is most destructive in April and May, at the time of maturity of its host. Since bur clover is a winter annual and the seed may remain dormant from May until the following autumn, interest is attached to the annual reappearance of the disease.

It was found by an examination of the centrifuged washings of bur clover seed, from collections made during July, August and September, that Cercospora conidia were commonly present. It is probable that the introduction of leaf spot to new localities is due to the presence of viable conidia on the surface of the burs. That these conidia remain viable is indicated by the fact that the cotyledons of seedling bur clover plants have been observed under field conditions to be affected with Cercospora. The disease then spreads to the true leaves, as soon as they are formed, and the leaf spot organism lives over winter in leaf spots on the sheltered leaves.

Preliminary tests indicate the possibility of controlling its further spread by seed treatment. Immersion for one minute in boiling water, a treatment designed to hasten germination of the bur clover seed, seems at the same time to destroy the viability of the conidia. Plants grown from seed treated with formaldehyde were also free from leaf spot.

FREDERICK A. WOLF

Neocosmospora vasinfecta Erw. Sm. on potato and adzuki bean. During the season of 1915, the perithecial stage of *Neocosmospora vasinfecta* has been found at Auburn, Alabama, on two species of plants not previously recorded, Irish potato and adzuki bean (*Phaseolus angularis*). The specimens on Irish potato tubers were collected by Prof. A. B. Massey. The perithecia had formed on the surface of the tubers, being especially abundant around the "eyes," with no evidence of decay. Decomposing organic materials in the soil appear to have served as the source of food for the vegetative growth of the fungus.

The perithecia appeared upon the dead stems of adzuki beans. These beans had been grown on wilt-infested soil and beyond doubt had succumbed to the attacks of Fusarium.

The fungus on both of these species agrees morphologically with *Neocosmospora vasinfecta* from peanuts, with which it has been compared and is therefore believed to be identical with it.

FREDERICK A. WOLF

Sclerotium rolfsii Sacc. on Citrus. *Sclerotium rolfsii* is known to occur ubiquitously throughout the Southern States upon a wide range of hosts. A recent paper (Earle, F. S., and Rogers, J. M., "Citrus Pests and Diseases at San Pedro in 1915," 1st Ann. Rpt. San Pedro Citrus Pathological Laboratory, San Pedro, Isle of Pines, W. I., p. 3–41, figs. 19, 1915) records for the first time that it is capable of producing a rot of Citrus fruits when they come in actual contact with the soil. During the past season this fungus caused the death of seedling grapefruits (*Citrus decumana*) in the greenhouse at Auburn, Alabama. The soil in which these seedlings were grown was infested with *Sclerotium rolfsii* from some inoculation tests conducted during 1914. Infections were first evident on the stems at points near or several inches above the ground level. The diseased cortex was brown, in sharp contrast with the normal green tissues. Within a week the little trees had been girdled and were dead and dry. Soon afterward sclerotia formed on these dead seedlings. The organism was isolated in pure culture from these seedlings and to all appearances was found to be identical with a culture of *Sclerotium rolfsii* obtained from diseased peanuts.

FREDERICK A. WOLF

Spread of the chestnut blight in Pennsylvania. Mr. I. C. Williams, Deputy Commissioner of Forestry of Pennsylvania, has recently issued the following statement regarding the present status of the chestnut blight in Pennsylvania. In view of recent statements circulated in the newspapers, apparently by nursery interests, to the effect that the chestnut blight is coming to a standstill, this statement of Mr. Williams' is of considerable interest to plant pathologists.

HAVEN METCALF

Since the Chestnut Blight Commission has passed out of existence, the Department of Forestry has been keeping an eye on the blight situation in Pennsylvania. Recently the statement has been made frequently that the blight has run its course and is gradually dying out in the State. To discover the truth of this statement, the Department addressed a circular letter to fifty-four of its foresters, covering forty counties, asking if the blight was spreading, receding, or apparently stationary in their districts.

Replies have been received from fifty of the foresters. Twenty-eight report the blight spreading rapidly; eight report that it is apparently stationary; one reports it receding; and fourteen report no blight on or near their forests.

The infection reported farthest west is in northwestern Clearfield county; that farthest east in central Pike county; that farthest north in northwestern Tioga county; and that farthest south near the Maryland line in Franklin county.

Pinus resinosa, a new host for Peridermium acicolum. In June, 1915, while at Itasca Park, Clearwater County, Minnesota, the writer found

about one mile from the Minnesota Forest School headquarters, an open stand of young red pine (*Pinus resinosa* Ait.) from two to eight feet in height, of which practically all the trees examined, numbering seventy-five, were more or less affected by a needle rust. Specimens (F. P.[1] 18064 and F. P. 18065) were sent to Washington, D. C., and the fungus identified by Dr. George G. Hedgcock, of the Office of Forest Pathology, as *Peridermium acicolum* Underw. & Earle. The trees seen were in a clearing not far from the woods. Some of the small trees, under three feet in height, were nearly covered with the rust, which had the effect of stunting the trees. On the other hand, no noticeable injurious effect was seen on trees six to eight feet in height. On the larger trees the rust was much less abundant than on the smaller trees.

It has since been learned from Prof. J. H. Allison, of the University of Minnesota, present at the time of the first collection, that the rust on the red pines extended into the woods from the young pines in the clearing, a distance of from forty to sixty rods. None of the trees in the woods were as badly affected as those in the opening, nor was there such a large percentage of them affected.

G. G. Hedgcock also collected *Peridermium acicolum* on a single seedling of *Pinus resinosa* (F. P. 17799) in a nursery near Caledonia, Pennsylvania, in June 1915.

As far as known to the writer this is the first time that a rust has been reported on *Pinus resinosa*.

ROY G. PIERCE

The Rio Grande lettuce disease. A preliminary survey of the trucking section of southeastern Texas has shown the presence of a disease of lettuce not hitherto described. This disease occurred to a slight extent last year and it has been particularly destructive this year in the large acreage of this crop in the Rio Grande Valley. Since no similar disease of lettuce is known to the writer it was considered advisable to record the symptoms as observed. To distinguish this disease from other troubles of lettuce the name Rio Grande disease is suggested.

The disease is manifested by the general symptoms of an impoverished and gradually dying plant. These gross symptoms may be grouped as follows: (1) reddening of the older leaves and blanching of the younger, central leaves, (2) restricted development of newly forming leaves, accompanied by small, dark-colored, blister spots along the border, (3) development of numerous lateral adventitious shoots, and (4) dry and dead small roots. The general appearance of the disease differs with the age of the affected plants, the symptoms being present in varying degrees.

[1] F. P. = Forest Pathology Investigations' number.

FIG. 1. Lettuce plant affected with the Rio Grande disease, showing the development of numerous adventitious shoots; also heart leaves from plant affected with the disease, showing the characteristic blister spots along the margins.

The younger plants cease to grow, gradually turn red, and die. Half-grown plants, if affected, are readily detected at some distance by the blanched appearance of the center. Frequently also the outer leaves are reddened. If the central leaves are pulled apart, exposing the growing small leaves, it will be seen that the latter present the spotted appearance along the border as illustrated in the figure. These spots are more or less blister-like and contain, under the epidermis, a brown, pulpy mass of disorganized tissue. A more advanced stage of the disease is accompanied by a further disorganization and drying down of the tissues of the growing parts.

An additional symptom commonly observed on plants of the size to form heads is manifested by the development of a large number of adventitious shoots. A closer observation showed that the small roots of all affected plants which were examined were dead, the cortex readily slipping from such roots. No parasitic insects or fungi were found constantly associated with this disease. However, microscopic observations were limited to those which could be made with field equipment.

Since all of the observed symptoms indicated a root trouble a few preliminary chemical analyses[1] were made of the irrigation water used and of the soil about affected plants. The results of these analyses, considered in addition to other available analyses[2] of Rio Grande River water, indicate that the alkali problem is sufficient in this locality to offer a partial explanation of this disease of lettuce.

C. W. CARPENTER

Rhizoctonia and Sclerotium rolfsii on sweet potatoes. Rhizoctonia has been commonly found causing considerable damage to young plants in the hotbeds in Florida and Alabama and to a less extent in New Jersey. In the South the fungus causes a decay of the underground parts of the stem. The leaves turn yellow, the plant remains dwarfed, and finally dies. In New Jersey the same fungus is suspected of causing dark, sunken cankers on the stem of the plant, near the soil line. These cankers are at first small, but spread up and down and around the stem, and may eventually bring about the death of the plant. If, however, the disease is not too far advanced, affected plants may be set in the field without risk. The Rhizoctonia disease in the South was found to be more prevalent in beds that had been too frequently watered.

Sclerotium rolfsii has been found only in the South, and most de-

[1] The writer is indebted for these analyses to Mr. F. M. Scales, of the Office of Soil Bacteriology Investigations, U. S. Department of Agriculture.

[2] Clark, F. W. The data of geochemistry. U. S. Geological Survey Bul. 330: 69. 1908.

structive in Florida and Texas. This fungus spreads from the point of infection in a circular-like manner, destroying nearly all the plants with which it comes in contact over areas of a foot to several feet in diameter and sometimes over nearly the whole hotbed. It is most destructive during cloudy, wet weather and when the mat of leaves prevents the surface of the soil from drying out. Under such conditions a white mass of hyphae spreads over the soil and lower part of the stems and lower leaves. Later numerous sclerotial bodies of the fungus are developed.

L. L. HARTER

Reproduction of autochrome plates. The colored plate illustrating the article by Dr. V. B. Stewart (Phytopath. **6**: plate II) is a reproduction from a Lumiére autochrome plate and was secured through the courtesy of Dean B. T. Galloway of the Cornell University Agricultural Experiment Station. The original plate seemed to show too much yellow but the leaf was young and perhaps was more yellow than a fully developed leaf. The reproduction is very faithful and leaves little to be desired. In fact the brown shades seem to be better in the reproduction than in the original.

The four engravings from which the reproduction was printed were made by the Matthews-Northrup Works, Buffalo, New York. Mr. George E. Matthews, President of the company, has kindly furnished the following statement of the method employed:

> The autochrome is placed in a shadow box with a strong reflected light behind it. The camera is focussed sharply and the intervening space completely darkened thus centering the light on the autochrome.
>
> Four halftone negatives are then made filtering the various colors, one each to print yellow, red, blue and black. The angle of the screen is turned between each exposure as may be seen readily by examining the print with a hand lens. This prevents a "pattern" or smudgy appearance. The halftone screen negatives are then printed on a prepared copper plate just as one would print on photographic paper from a negative.
>
> After the halftone negatives have been printed on copper, the plates are ready for etching. The finishing of the plates depends upon the skill of the re-etcher, who has to do the work that the camera cannot do. A camera has not yet been made, which when used with filters, will get absolute separation, so when the plates are first etched, they are usually not a very close reproduction of the object, and re-etching is necessary until all the tones and values of the original subjects are reproduced just as they are in the original.
>
> In order to obtain the best results, it is important to have as nearly a perfect autochrome as possible.
>
> Reproducing colored work from autochromes is more difficult than reproduction from a painting or actual object, as one has to contend with light reflection, which is very likely to change the color of the object from one moment to the next.

DONALD REDDICK

REPORT OF THE RIVERSIDE MEETING OF THE PACIFIC DIVISION OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

A meeting of the Pacific Division was held at Riverside, California, in the rooms of the Plant Breeding Division of the Citrus Experiment Station, December 29, 1915.

Dr. J. T. Barrett, Vice-President, opened the meeting and expressed regret at the loss to the Division of its President through the removal of Professor Jackson to fields of labor outside the Pacific Slope district.

The Secretary explained that affiliation with the parent Society lacked only the approval by that Society of its Committee's action, the conditions having been approved already by this Society. Affiliation is also pending with the American Association for the Advancement of Science, Pacific Division. It was moved and carried that the matter of the next meeting be left to the Executive Committee to decide. The opinion was expressed by the members that two independent meetings per year is more than is needed to present the work of the members and caused considerable effort in the way of long journeys.

Dr. H. J. Webber suggested the propriety of this Society taking some action regarding the citrus canker disease, calling attention to the great importance of the citrus industry in the district covered by this Society, to the seriousness of the disease where it occurs, to the absence of any evidence that it would be less serious if introduced in groves of the Pacific Slope, and the great probability that it will be introduced into California if not suppressed in the eastern United States, and to the respect which the opinion of this Society should command from those responsible for deciding on the support to be given the project for eradicating the disease. On motion of Dr. H. S. Reed the Society resolved itself into a Committee to draw up appropriate resolutions in the matter to be addressed to the Committees of Congress. After due deliberation the Committee arose and the Society met in executive session to consider the report. On motion of Professor Reed, seconded by Professor T. F. Hunt, the following resolution was unanimously adopted:

"The American Phytopathological Society, Pacific Division, in regular session at Riverside, California, after discussion of the subject of Citrus Canker disease, has adopted the following resolution:

Whereas, since the disease was discovered in this country it has been found that it very quickly and easily spreads from one section to another, and that the injury from the disease has proven to be very disastrous to the industry in sections where it occurs; and because we believe it can be controlled;

Resolved, that this Society regards the Citrus canker disease a serious menace to the citrus industry of the United States, and

Resolved, that we urgently request your honorable body to give your moral and financial support to the best and most immediate measures for stamping out this disease where it now occurs, and to take whatever measures seem necessary to prevent further spread of the malady."

The Secretary was instructed to send copies of the resolution to members of the Agricultural Committees of Congress, to members of this Society and such other persons as might be interested.

The Secretary was instructed to send a telegram to Mr. Asbury F. Lever. The following telegram prepared and approved by the Society, was sent:

"HON. ASBURY F. LEVER,
Chairman, Agricultural Committee,
House of Representatives,
Washington, D. C.

Resolved that this Society in session regards the citrus canker disease as a serious menace to the citrus industry of the United States and

Resolved that we urgently request your honorable body to give your moral and financial support to its eradication.

(Signed) AMERICAN PHYTOPATHOLOGICAL SOCIETY,
Pacific Division,
WM. T. HORNE Secy."

The following papers were presented:

Notes on Oleander bacteriosis. C. O. SMITH.

Oleander bacteriosis is occasionally found in California on nursery stock and has been before reported and more or less carefully described from Italy and California.

The organism causes galls on the stem, leaves and inflorescence, which closely resemble the olive knot, *Bacterium savastanoi*, and the aerial galls produced artificially by *Bacterium tumefaciens*.

From the study thus far made, certain differences have been determined between the oleander organism and the other two gall-producing organisms. The oleander organism is able to cause knots by artificial inoculations on the olive and oleander, but gave negative results on the following plants that are susceptible to *Bacterium tumefaciens*, as shown by parallel artificial inoculations: Wickson plum (*Prunus*), *P. persica*, *P. amygdalus*, *P. cerasifera* and *Shinus molle*. The olive knot organism gave negative results on oleander. The olive was much more resistant to *Bacterium tumefaciens* than to the oleander organism, and the galls that developed were not one-tenth the size.

A new leaf-spot disease of cherries. BERT A. RUDOLPH

A cherry leaf-spot disease occurs on leaves of sweet cherry at a number of points in California and Oregon. The spot is rather large, brown, usually definitely bounded. It appears to originate, in many but not all cases, at an insect mine. An insect of the group Chalcididae has frequently been found in these mines but no other. No fungous spores or fruiting bodies were found on the spots occurring in nature, but tissue plantings on sterile media repeatedly yielded a fungus of the genus Alternaria. Single-spore cultures repeatedly gave the typical spot when inoculated into healthy leaves and the fungus was repeatedly and regularly reisolated from the artificial spots. Comparison with *Alternaria citri* Pierce and a species of Alternaria on watermelon leaf-spots in cultures showed the three fungi to be very similar but distinguishable by certain reactions.

Non-parasitic stem lesions on seedlings. CARL HARTLEY

Attention is called to a disease affecting the bases of the stems, and resulting in death of considerable numbers, of very young seedlings of conifers and various herbaceous plants. For this the name white spot is proposed. Though in many ways resembling parasitic damping off, and commonly confused with it, evidence is presented indicating that the trouble is caused by high temperature at the soil surface,

possibly combined with the effects of light. Loss from white spot can be decreased by partial shade and apparently by frequent watering. White spot lesions are distinguished from damping off infections by their light color, definite boundaries, and limitation to the part of the stem above the soil surface.

A basal girdling of two- to three-years-old stems has been attributed by Münch to the same cause as white spot. The correctness of Münch's view is questionable, for in the United States the disease of the older plants is almost entirely absent from the nursery in which the most white spot has been observed, and causes serious loss at a nursery where white spot is less common.

Observations on sour sap disease of apricots. EDITH H. PHILLIPS

Apricot trees affected with so-called sour sap or black heart show distress first in the outer branches, which begin to die back and in the wood of which are found brown streaks. Frequently one side of a tree goes in this way and occasionally a whole tree dies outright. Excision well below the darkened wood does not stop the advance o the disease. This trouble appears during summer and fall and is said to be particularly abundant in a wet year following one or two dry years.

Cultures of soil protozoa were made with roots with adhering soil, associated with diseased trees in one of the badly affected orchards, and with soil from the crowns of apparently healthy trees in the same orchard. Four cultures from material associated with diseased trees and two cultures from soil at the crowns of two apparently healthy trees were made. The protozoan faunas of the former cultures were found to be more diverse and abundant than those of the latter.

Factors influencing the distribution of certain Citrus diseases. H. S. FAWCETT

No abstract.

Red leaf-spot of Hippeastrum. PAUL I. DOUGHERTY

Conspicuous red spots, usually rather small in size, occur on the cultivated Hippeastrums or spring-flowering Amaryllis, causing blemishing and occasional deforming of leaves, scapes and flowers. Importance of the disease arises from the high value of individual plants and the desirability of producing them in entirely perfect condition. Hand sections of spotted tissue placed in drop cultures gave rise to an abundant mycelium. Homogeneous growth from this planted in sterile media grew vigorously, and on artificial inoculation into wounds produced the typical spots. The same fungus was reisolated from the artificially produced spots and infection again produced on healthy leaves. A Phyllosticta type of fruiting body with spores was developed in certain media and the typical fungus grown from single spores. Inoculations from the single spore cultures were also successful.

Phomopsis Mali on young apple and pear trees in California. ELIZABETH H. SMITH

Attention is called to a disease of young apple and pear trees found in California which very nearly resembles that reported in 1912 by J. W. Roberts in Virginia. The disease is caused by a fungus, named by Roberts *Phomopsis Mali*, which forms extensive cankers on the limbs, the bark affected being finally covered with the spore coils emitted from protruding pycnidia.

The trouble has been found only on one- to three-years-old trees, and thus far is of no economic importance in California.

Notes on control of walnut blight by spraying. W. S. BALLARD

No abstract.

A Gloeosporium disease of the almond probably new to America. HELEN L. CZARNECKI

In March, 1915, specimens of diseased almonds from Napa County, California, were sent to the University of California for examination. Investigations were made by the writer and the disease was found to occur to a limited extent in several orchards in Napa and Alameda Counties.

The disease appears mainly on the young green fruits, producing large, brown- to orange-colored, sunken spots, and often causing the fruits to wither and finally drop. The leaves of the younger branches show numerous confluent shot-holes.

The causal fungus is a species of Gloeosporium, apparently the same as that found on the almond in Italy and named *Gloeosporium amygdalinum* by Dr. Ugo Brizil of the Royal Phytopathological Experiment Station at Rome.

No previous record of the occurrence of this fungus in America has been found.

Some new applications of Plant Pathology. H. S. REED

No abstract.

The winter state of Synchytrium decipiens. J. T. BARRETT

No abstract.

A new species of Pythiacystis. J. T. BARRETT

No abstract.

LITERATURE ON AMERICAN PLANT DISEASES[1]

COMPILED BY MISS E. R. OBERLY, LIBRARIAN, BUREAU OF PLANT INDUSTRY

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Adams, J. F. A Gloeosporium on horse-chestnut shoots. (Abstract.) Phytopathology **6**, no. 1: 114–115. February, 1916.

Appel, Otto. International phytopathology. (Abstract.) Phytopathology **6,** no. 1: 55–63. February, 1916.

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[1] This list aims to include the publications of North and South America, the West India Islands, and islands controlled by the United States, and articles by American writers appearing in foreign journals. All authors are urged to coöperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles published outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. Agric., Washington, D. C.

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